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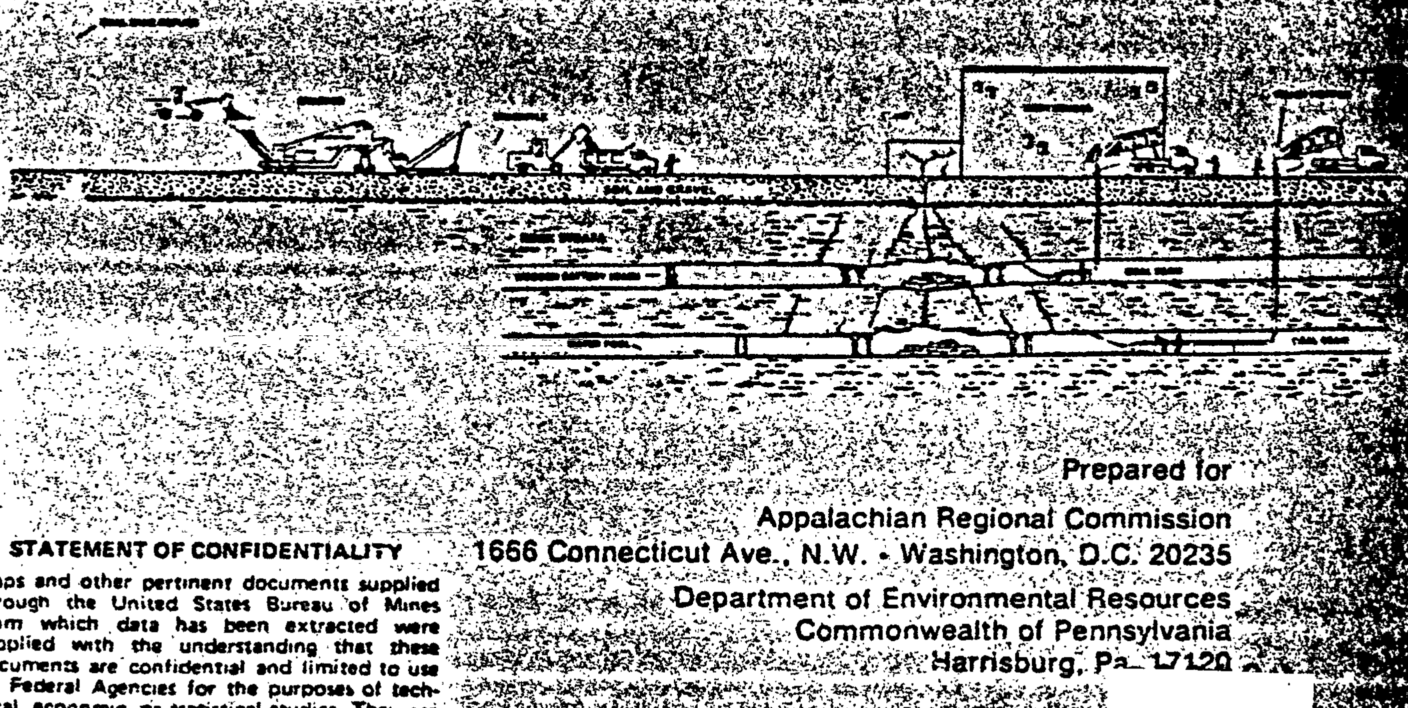
Report ARC—73-111-2552 114607

Overview of Subsidence Potential in Pennsylvania Coal Fields

HRB-Singer, Inc., Science Park, State College, Pa. 16801

The material in this report is based on the best information available at the time of report preparation. The data should be updated by the reader as new information becomes available. Conclusions are abased on an overview of the area and are not site specific. In all Class I and II areas an engineering evaluation should be made.

30 JUNE 1975



Prepared for

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16. Abstracts

This study is part of a comprehensive program on mining activities, the associated surface subsidence effects, and their correlation with post-hurricane Agnes reconstruction projects in Pennsylvania. The objective was to develop a methodology which would permit the classification of land areas within the Anthracite Region in terms of their potential to mine incurred subsidence. The effort was directed toward establishing criteria and evaluation techniques for the prediction of subsidence potential and presentation of such potential classifications in a manner convenient for subsequent risk evaluations.

A subsidence data base was developed, for the Anthracite Region of northeastern Pennsylvania, based on 25 critical parameters upon which an algorithm operated to classify 40 acre land elements into three categories of subsidence potential. These computer maps were produced for parts of 20 of the 36 U.S.G.S. 7½ minute quadrangles defining the Anthracite Region. Collateral information was used to complete the 36 quadrangles in terms of information on past mining history.

The algorithm was tested in the Bituminous coal fields of Pennsylvania and Maryland and operated in a similar manner to that in the Anthracite fields.

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DISSENTING OPINION OF THE LOCAL SUBSIDENCE REVIEW COMMITTEE

It is the considered opinion of the members of the Local Subsidence Review Committee that the methodology and conclusions drawn in the Overview of Subsidence Potential in Pennsylvania Coal Fields Study present an incomplete and, therefore, in specific locations, inaccurate representations of subsidence potential in Northeastern Pennsylvania. We, therefore, strongly enter our dissent to the Report. The basis for expressing these reservations originates from a well established tradition of sound industrial land development, reliance on mining engineers familiar with site conditions, and the development of specific information on land stability characteristics.

We also disagree with the methodology employed in the design and implementation of the study, particularly for lack of input by local professional mining engineers and industrial development agencies who are intimately acquainted with specific local conditions. Therefore, we believe that the conclusions drawn by the study must be reviewed with extreme caution and reservation by the reader. The following reasons explain our minority opinion.

1. The report assigns subsidence potential classifications to 40-acre tracts of land on the basis of the worst conditions found in as little as 10% of the land area.

2. The primary source of information; namely, U. S. Bureau of Mines map folios, are in many respects incomplete in that maps for all areas are not available. Even in the cases where mine maps are available, these folios are in and of themselves incomplete in that they reflect conditions which existed at the last recorded stage of mining. Uncharted mining activity and the passage of time have in many cases resulted in unrecorded stabilization of those land areas. This report and the computer model does not reflect those stabilizations. In this respect, the data and parameters used in the computer model must be viewed with extreme caution.

3. Many areas characterized as having subsidence potential are sites of substantial development which was not initiated without detailed site engineering reports by mining engineers familiar with local conditions. Examples of these anamolies may be found in Appendix A where specific instances are cited by Mr. Daniel Connelly, veteran Professional Mining Engineer.

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4. In the course of the past 25 years well over 300 manufacturing firms have located in Northeastern Pennsylvania. Detailed site evaluations of industrial land prior to development has resulted in the location of these firms without one incident of subsidence. Detailed information for these and other specific industrial sites is available from individual industrial development groups in Northeastern Pennsylvania.

In summary, we believe the use of the information contained in this report must be tempered by the knowledge that severe limitations exist for describing subsidence potential in the manner developed in this report.

Ernest D. Preate, SR.

Ernest D. Preate, Sr., President
- and -
Chairman
Local Subsidence Review Committee

Donald D. Meyer, Exec. V. P.
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of Commerce

Hugh L. Campbell, III, President
CAN-DO, Inc.

Edgar Lashford, Exec. V. P.
Greater Wilkes-Barre
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Vincent O'Hara, Exec. V. P.
Greater Pittston Chamber
of Commerce

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DEPARTMENT OF ENVIRONMENTAL RESOURCES REVIEW NOTICE

The material in this report represents only the best professional judgment of the consultant and is believed to be useful to the reader. The data presented in this report as well as the conclusions, recommendations and opinions are those of the consultant and are not necessarily those of the Department of Environmental Resources and the Appalachian Regional Commission. Since circumstances vary from site to site, the Department of Environmental Resources and the Appalachian Regional Commission cannot be responsible for any designs, plans, or construction derived from or based upon this data and material. All readers are cautioned to use their own consultants to obtain data and develop designs and plans for their own uses.

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This study was performed by the Energy and Environmental Resource Analysis Group of the Environmental and Social Analysis Department of HRB-Singer, Inc. The effort was performed under the direction of Dr. S. B. Cousin, Director of the Environmental and Social Analysis Department with Dr. Ronald Stingelin as Principal Investigator and Mr. Edward Baker as Project Engineer. The work was performed under the technical cognizance of Dr. John Demchalk and Mr. Edward Bates of the Pennsylvania Department of Environmental Resources, Office of Resources Management, Bureau of Resources Programming and received helpful guidance from Dr. David Maneval of the Appalachian Regional Commission whose organization sponsored the effort.

The Energy and Environmental Resources Analysis Group of HRB-Singer, Inc. extends thanks to the following groups and individuals for their invaluable assistance in the various tasks for successful completion of this project:

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Mine Pool Elevation Monitoring Map and Monthly listing of mine pool elevations, Mr. Stephan Yanchek, Operations Supervisor for providing assistance on collection of information on office operations.

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Thanks go also to personnel of the County Assessment and Planning Offices for the status of planning on a county and local level.

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

This effort was part of a comprehensive program for the study of the surface subsidence effects associated with underground mining activities in the Anthracite Region of Pennsylvania and the correlation of these effects with post-hurricane Agnes (June 1972) reconstruction projects. This effort was one of eleven projects funded by the Appalachian Regional Commission through the Commonwealth of Pennsylvania, Department of Environmental Resources.

This study addressed the development of a technique for projecting the subsidence potential of undermined land areas based on past mining activity history and the characteristics of the subsurface features in the areas of mining operations.

Specific objectives of the investigation were:

1. To develop a mining information data base for the Anthracite fields.
2. To establish criteria and evaluation techniques that will permit an accurate, economical evaluation of subsidence potential.
3. To produce subsidence potential maps to assist in long-range planning projects relating to mine stabilization, urban redevelopment, and future mining practices within the region.
4. To test the evaluation as to its applicability in the Bituminous Region of Pennsylvania and Maryland.

All of these objectives have been accomplished. Additional material relating to stratigraphic correlation of coal seams have been developed during the course of the study and is included in the documentation of the effort.

Land areas of approximately forty acres in size were chosen as the basic resolution element to which the collected mining information in the data base was correlated. Since the resultant classification maps were intended for use in risk assessment analysis, a worst case viewpoint was consistently employed throughout the data collection process. The reader is specifically cautioned, therefore, when considering the use of this data, not to infer subsidence characteristics for areas smaller than the forty acre element size on which this data analysis is based.

Data was collected for each forty acre element from mine map folios prepared by the United States Bureau of Mines, mine maps not incorporated in mine map folios, U.S.G.S. geologic quadrangle map series, coal investigation map series, special investigation map series, the Second Pennsylvani Topographic and Geologic Survey bulletins, aerial photography, and the topographic quadrangles themselves.

The data covered 25 key critical parameters and were entered into a computerized data base. Engineering experience was utilized to develop an algorithm which would provide for systematic assessment of conditions in each of the forty acre elemental areas. The algorithm developed combined collapse likelihood with an empirical calculation of the total subsidence possible should collapse occur in all mined seams to result in a systematic assessment of subsidence potential. Three subsidence potential classes were used and are defined as Class 1 - "Precautionary Area" future subsidence probable if subsidence has not already progressed to completion. Site engineering recommended; Class 2- subsidence possible. $S_{MAX} > 0 <$ 0.5 feet. Site engineering recommended; and Class 3 - no subsidence. $S_{MAX} = 0$ feet.

The algorithm was exercised on a total of 3106 elements in the Northern Field, 880 elements in the Western Middle Field, and 295 elements in the Southern Field. These comprise all the elements where sufficient mine map data was available. The remaining elements in the Anthracite fields were treated by reporting stripping, deep mining, robbing, no mining, and combinations of these activities.

In the Northern Field, the algorithm was exercised for the complete field with the one exception of the Stackhouse Colliery (less than one percent of the total number of elements) at the extreme southwestern end. Sixty-six percent of the elements were included in subsidence potential Class 1, eleven percent in Class 2, and twenty-two percent in Class 3. Because of the incomplete data for the remaining fields, a statistical summary would not be meaningful. The Northern Field is used as an example of what can be done when complete data is available.

Testing of the algorithm occurred in the Bituminous coal fields of western Centre County, Pennsylvania and western Allegany County, Maryland. Results were similar to those obtained by exercising the model in the Anthracite Region.

The extensive correlation of coal seams in the Northern Anthracite Field provided in this report contributes to the usefulness of the overall data base. Additional map displays and statistical information may be derived from the data base which is designed for continuous update and the addition of new parameters.

The algorithm developed in this study is regarded as an interim product requiring further development. It represents the first attempt at the development of a meaningful predictive subsidence potential model which can cost effectively be applied over large regions. It represents a new contribution to the knowledge of subsidence prediction and forms the basis for further development both in the use of predictive models in operational regional planning and in the correlation of subsidence occurrence to the coal seam conditions present in the Anthracite and Bituminous mining regions of Appalachia.

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1. BACKGROUND

1.1 INTRODUCTION

This report presents the findings and recommendations of an intensive study performed by HRB-Singer for the Commonwealth of Pennsylvania; Department of Environmental Resources under Contract EER-121 "Overview of Subsidence Potential in Pennsylvania Coal Fields." The study is part of a comprehensive program on mining activities, the associated surface subsidence effects, and their correlation with post-hurricane Agnes reconstruction projects. The overall program is funded by the Appalachian Regional Commission through the State of Pennsylvania. The State monitor for Contract EER-121 is the Department of Environmental Resources through the Office of Resources Management. A complete list of the associated projects comprising the comprehensive program and the performing research agency or subcontractor is presented in Table 1.

1.2 DISCUSSION OF THE PROBLEM

Subsidence is the term applied to the settling of the earth's surface as a result of natural or man-induced modification of the underlying supporting structure. As such the phenomenon is prevalent in many areas of the world. This is specifically true of regions in which the extraction of coal, mineral ores, oil or ground water has been intensively pursued. One such region is the Anthracite Region of Pennsylvania. While extraction of coal in this area has played an important role in the economic development of Pennsylvania during the past century the lingering effects of the associated subsidence must be coped with if future development in this area is to flourish. Recognition of this fact prompted the Pennsylvania Department of Environmental Resources to initiate a coordinated program in conjunction with ARC to develop and implement techniques and projects to combat the effects of subsidence.

In this coordinated program the full range of existing alternate strategies for coping with subsidence (flushing, insurance programs,

TABLE 1 ARC-DER SUBSIDENCE CONTRACTS

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PROJECT	SUBCONTRACTORS AND RESEARCH AGENCY	SCOPE OF WORK
EER-119	GENERAL ANALYTICS	SURFACE STABILIZATION - STATE OF-THE-ART ACTIVE MINING TECHNIQUES TO MINIMIZE SUBSIDENCE
EER-120	MICHAEL BAKER, JR., INC.	ARCHITECTURAL MEASURES TO MINIMIZE SUBSIDENCE DAMAGE
EER-121	HRB-SINGER, INC.	OVERVIEW OF SUBSIDENCE POTENTIAL IN PENNSYLVANIA COAL FIELDS.
EER-122	A. W. MARTIN ASSOCIATES	RELATIONSHIP BETWEEN UNDERGROUND MINE WATER POOLS AND SUBSIDENCE IN THE NORTHEASTERN PENNSYLVANIA ANTHRACITE FIELDS.
EER-123	EARTH SATELLITE CORP. VIA OFFICE OF PLANNING & RESEARCH, DEPARTMENT OF ENVIRONMENTAL RESOURCES	USE OF PHOTO INTERPRETATION AND GEOLOGICAL DATA IN THE IDENTIFICATION OF SURFACE DAMAGE AND SUBSIDENCE.
EER-124	MARCOU, O'LEARY & ASSOC. VIA OFFICE OF STATE PLANNING AND DEVELOPMENT, GOVERNOR'S OFFICE	LAND USE ECONOMICS AND SOCIAL INDICATORS IN SUBSI-DENCE PRONE AREAS.
EER-125	MULLIN & LONERGAN ASSOC., INC. VIA OFFICE OF STATE PLANNING AND DEVELOP-MENT, GOVERNOR'S OFFICE	LOCAL AND STATE REGULATORY POWERS DEALING WITH LAND USE AND CONSTRUCTION IN SUBSIDENCE PRONE AREAS.
EER-126	A. W. MARTIN ASSOC., INC. VIA BUREAU OF LAND PROTECTION, DEPARTMENT OF ENVIRONMENTAL RESOURCES	DEVELOPMENT OF A COMPREHENSIVE PROGRAM OF INSURANCE PROTECTION AGAINST MINING SUBSIDENCE AND ASSOCIATED HAZARDOUS LOCATION RISKS.
EER-127	MICHAEL BAKER, JR., INC.	COMPREHENSIVE SUBSIDENCE PLAN.
EER-128	MICHAEL BAKER, JR., INC. VIA THE PENNSYLVANIA FISH COMMISSION	EVALUATION OF THE ENVIRONMENTAL IMPACT TO APPALACHIAN PENNSYLVANIA WATERS OF THE 1972 FLOOD AND SUBSEQUENT STREAM CHANNELIZATION WITH FUTURE POLICY RECOMMENDA-TIONS.
EER-129	OFFICE OF PLANNING & RESEARCH, DEPARTMENT OF ENVIRONMENTAL RESOURCES	THE DEVELOPMENT OF ENVIRONMENTAL GUIDELINES FOR LAND USE POLICY APPLICABLE TO FLOOD PRONE AND MINE SUBSI-DENSE PRONE AREAS IN PENNSYLVANIA.

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architectural measures, etc.) is being explored for appropriate application. At the heart of such considerations is an effective technique for projecting the subsidence potential of affected land areas based on the history of past mining activities and the characteristics of the subsurface in areas of mining operations.

The ability to anticipate subsidence over mined areas has been addressed in the literature and is founded on established physical principles of rock mechanics, a thorough discussion of which is included in Section 2.1 of this report. There is no established technique for predicting when subsidence will occur. However, the critical parameters required for the effective assessment of land area's potential to subsidence have been established on the basis of past mining experience both in Europe and in the U.S. The principle problem in establishing subsidence potential for any given region, therefore, is the lack of a reliable data base from which subsidence potential and risk predictions can be made.

As a result, a major portion of the activity in this study comprised the inspection of existing mining information, extraction of the parameters pertinent to the subsidence consideration and the synthesis of this information into a data base to be used in the potential classification. To keep this effort within practical limits, land areas of 40 acres in size were chosen as the basic element to which the collected mining information in the data base was correlated. A detailed discussion of the 40 acre element as the basic mapping unit is given in Section 2.2.2 of this report. In addition, since the resultant classification maps were intended to be used in risk assessment analysis, a worst case viewpoint was employed consistently throughout the data collection process, i.e. those areas of the mined seams within each elemental area reflecting characteristics that were most vulnerable to subsidence were selected for characterization of the entire 40 acre basic element. For these two reasons, it cannot be overemphasized that the classification maps presented in this report are for use in gross risk evaluation and reclamation planning. More detailed analysis of the type described in reference 2 is definitely required for site-specific planning activities. The reader is specifically cautioned, when considering the use of this data not to infer subsidence potential characteristics for areas smaller than the 40 acre element size on which this data analysis is based.

1.2.1 Objectives. The objective of this program was to develop a methodology which would permit the classification of land areas within the Anthracite Region in terms of their potential to mine incurred subsidence. The technical tasks performed to meet this objective are summarized briefly below:

1. Data Base development.
2. Establish criteria and evaluation techniques that will permit an accurate, economical evaluation of subsidence potential and risk.
3. Develop an algorithm that will permit the application of the established criteria to the land areas to be classified.
4. Produce subsidence risk/potential maps to assist in long range planning in such areas as mine stabilization, urban redevelopment, and future mining practices within the area.
5. Test the algorithm in the Bituminous Region of Pennsylvania and in a selected area of Maryland.
6. Document the study.

In addition to providing the basic data for the development of potential classification methodology, the assemblage of data collected provides a mining activity and subsidence data base which here-to-fore has not existed. The design utilized in preparing this data base provides for the easy, periodic review and updating as future subsidence occurs, as the results of additional subsidence studies become available, and as further reclamation projects are pursued.

The data provides planners with information required to decide what approach should be taken in each situation to prevent or reduce subsidence damage. The data can assist in establishing long range planning policies for the Anthracite Region and act as a useful guideline for planning policies in other areas with similar problems.

1.2.2 Scope. The lack of a base of information on subsidence vulnerability for the Anthracite Region has been a hindrance to planners, developers, and to a cohesive post Hurricane Agnes rehabilitation effort. Therefore, Contract EER-121 was directed toward establishing criteria and evaluation techniques for the prediction of subsidence potential and presentation of such potential classifications in a manner convenient for subsequent risk evaluations. The criteria and the evaluation techniques that have been developed are employed via the exercise of an empirically based logic model which provides subsidence risk/potential classification maps for the Anthracite fields of Pennsylvania. Since the necessary data to support this model development was most complete in the Northern Field of the Anthracite Region, efforts were concentrated on developing a thorough mapping program for this field. The lack of complete data for the Eastern Middle Field and parts of the Western Middle and Southern Fields precluded exercise of the model for all elements in these areas. However, reconnaissance data in the form of aerial photography, topographic maps, geologic maps, vintage Pennsylvania Geologic Survey publications, isolated mine maps, and the interview of mine company personnel were used to fill gaps in the data base. From these data the presence of mining, strip mining, and no-mining was established for inclusion in the overall data base. This information was then used to develop the 36 quadrangle maps included in Section 3.3.2 of this report. These quadrangle maps show the claculated subsidence potential classification for each basic land element where complete mine map data was available in the Anthracite Region. The resolution size of the data selected for use in this study was forty acres.

Because of the availability of more data in the Northern Field, a careful correlation study was made of coal seams from colliery to colliery extending the work of Bergin and Robertson[7] from the Wyoming into Lackawanna Valley. These correlations are included in Section 2.4.

Finally the model was exercised in the Western Pennsylvania coal fields and in the coal fields of Western Maryland to test the applicability of the developed model to conditions in the Bituminous Region.

1.3 GEOGRAPHIC AREA OF INTEREST

The area of interest for the data collection and analysis effort consists of the Anthracite Region of Northeastern Pennsylvania. This region includes a distinct fourfold division into geographic areas. The present day distribution of a formerly extensive coal forming Paleoenvironment is shown in Figure 1 against a background grid of 7 1/2' quadrangles published by the U.S. Geological Survey. The Northern Field, comprising the Lackawanna and Wyoming Valleys, is the characteristically canoe-shaped structure occupying parts of thirteen quadrangles. The Western Middle Field and the Eastern Middle Field occupy or share parts of an additional 13 quadrangles. The Southern Field shares parts of three quadrangles with the Western Middle Field and includes 10 additional quadrangles. In total, 36 quadrangles were included in the base study.

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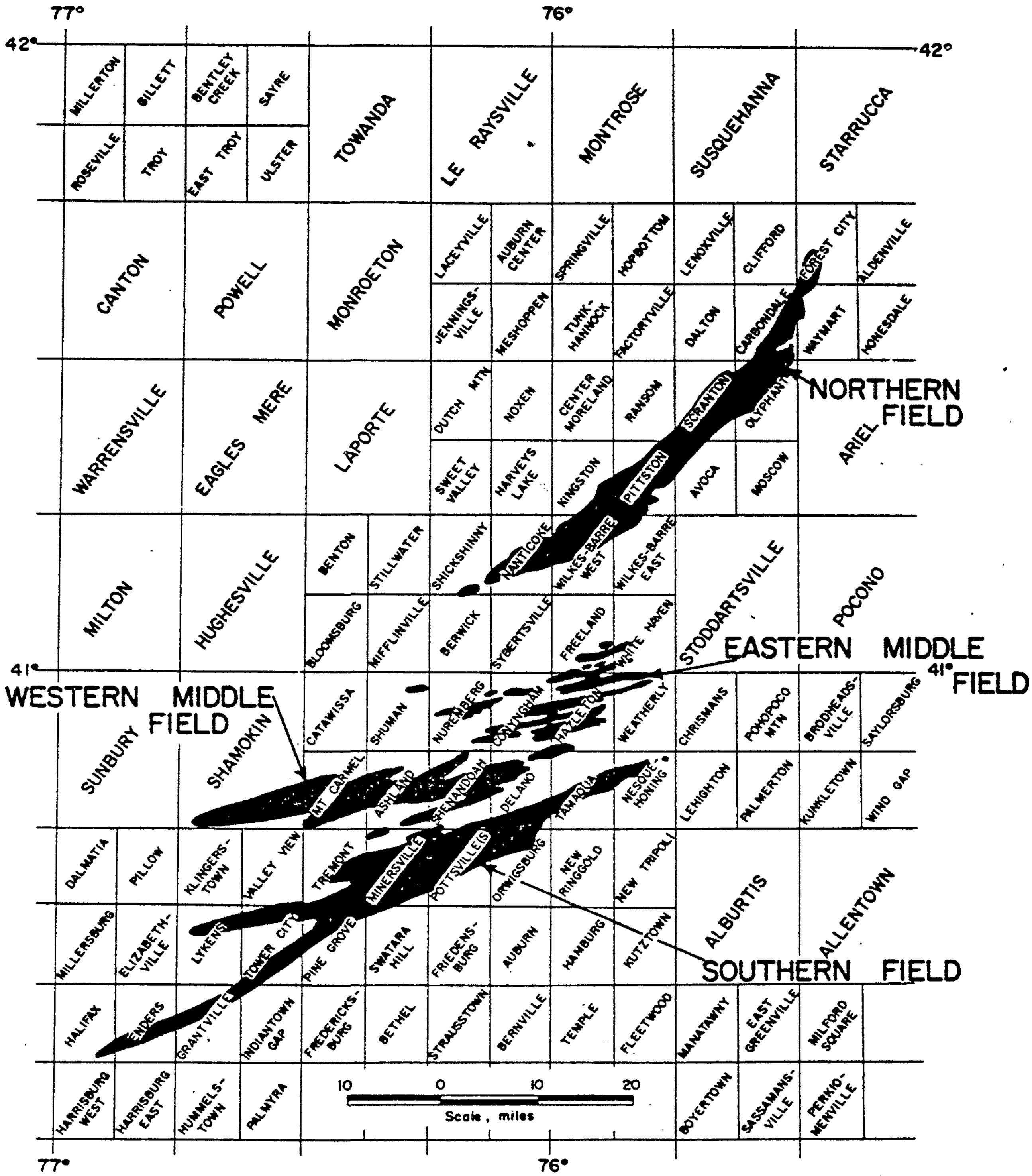

FIG. 1 THE FOUR ANTHRACITE FIELDS SUPERIMPOSED UPON AN INDEX GRID OF U.S. GEOLOGICAL SURVEY QUADRANGLE MAPS OF NORTHEASTERN PENNSYLVANIA

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Although located in a non-urban regional setting the four anthracite basins concentrate population into the valley bottoms and into those areas that have been extensively mined for coal in the past.

The four fields constitute an area of approximately 484 square miles of coal bearing terrane distributed over some 3,300 square miles in ten counties: Susquehanna, Wayne, Lackawanna, Luzerne, Carbon, Columbia, Schuylkill, Northumberland, Dauphin, and Lebanon. The coal fields are all topographic basins except for the Eastern Middle Field which is characterized by its topographic height, being a fairly level tableland whose edges drop off abruptly to surrounding lower terrain. LANDSAT channel 7 (IR) image of the Anthracite Region taken on 11 October 1972 (NASA ERTS E - 1080 - 15183 to 15185 - 7) is shown in Figure 2. The tableland aspect of the Eastern Middle Field and the mountain-ringed basin aspect of the other three fields are features clearly apparent in this image. The extensive surface mining activity that has marred this region in the past is evident by the dark tones on the LANDSAT image. The major river, the Susquehanna can be seen entering and leaving the Northern Field. The Lackawanna River joins the Susquehanna where it enters the Northern Field. These two rivers have presented the greatest threat to the region in terms of flooding. The effects of flood-induced subsidence are therefore felt most strongly in the Northern Field.

The Northern Field is also the most extensively urbanized, with large population centers in the cities of Wilkes Barre and Scranton.

The Western Middle Field includes the population centers of Shamokin, Mt. Carmel, Ashland, Girardville, Shenandoah, and Mahoney City.

The major population center in the Eastern Middle Field is Hazleton.

In the Southern Field major population is concentrated around Pottsville, Minersville, New Castle, St. Clair, Tremont, Tuscarora, Tamaqua, Coaldale and Lansford.

1.4 GEOLOGICAL CONSIDERATIONS

1.4.1 Introduction. The Anthracite fields of northeastern Pennsylvania lie in four arcuate structural depressions that trend northeastward across the east-central and northeastern parts of the State. This arcuate structural trend is quite evident on imagery taken by the LANDSAT Satellite (Figure 2) and is the topographic expression of composite folds or synclinoriums on which are superimposed numerous minor folds. The anthracite deposits occur in rocks of Pennsylvanian age that underlie the four separate coal basins. The rocks are all of continental origin and consist of lenticular deposits of conglomerate, sandstone, siltstone, claystone, shale, and the anthracite coal itself. The lower part of the stratigraphic sequence is predominantly conglomerate and the upper part mainly sandstone and shale.

This non-marine clastic sequence is indicative of the environmental conditions of the coal forming swamp during the Pennsylvanian Period. The Anthracite Region bears a close resemblance, in the physical properties of the coal and the clastic sediments (excluding metamorphic effects), to the low sulfur coals of southeastern West Virginia, Kentucky, and Tennessee and may be hypothesised to be part of the same depositional sequence beginning in the early Pennsylvanian Period. Deposition during Pottsville time is considered[6] to be in a narrow rapidly and differentially subsiding trough of the Appalachian Geosyncline with marine conditions far to the southwest and with restricted circulation to the northeast. As the troughs filled toward the close of Pottsville time, platform deposition was occurring west of a tectonic hingeline through central West Virginia (Figure 3) and spread throughout Pennsylvania in Allegheny time. Proximity to the sediment source and fresh water influx were factors that may have kept the sulfur content of the northeastern Anthracite Fields low while isochronous

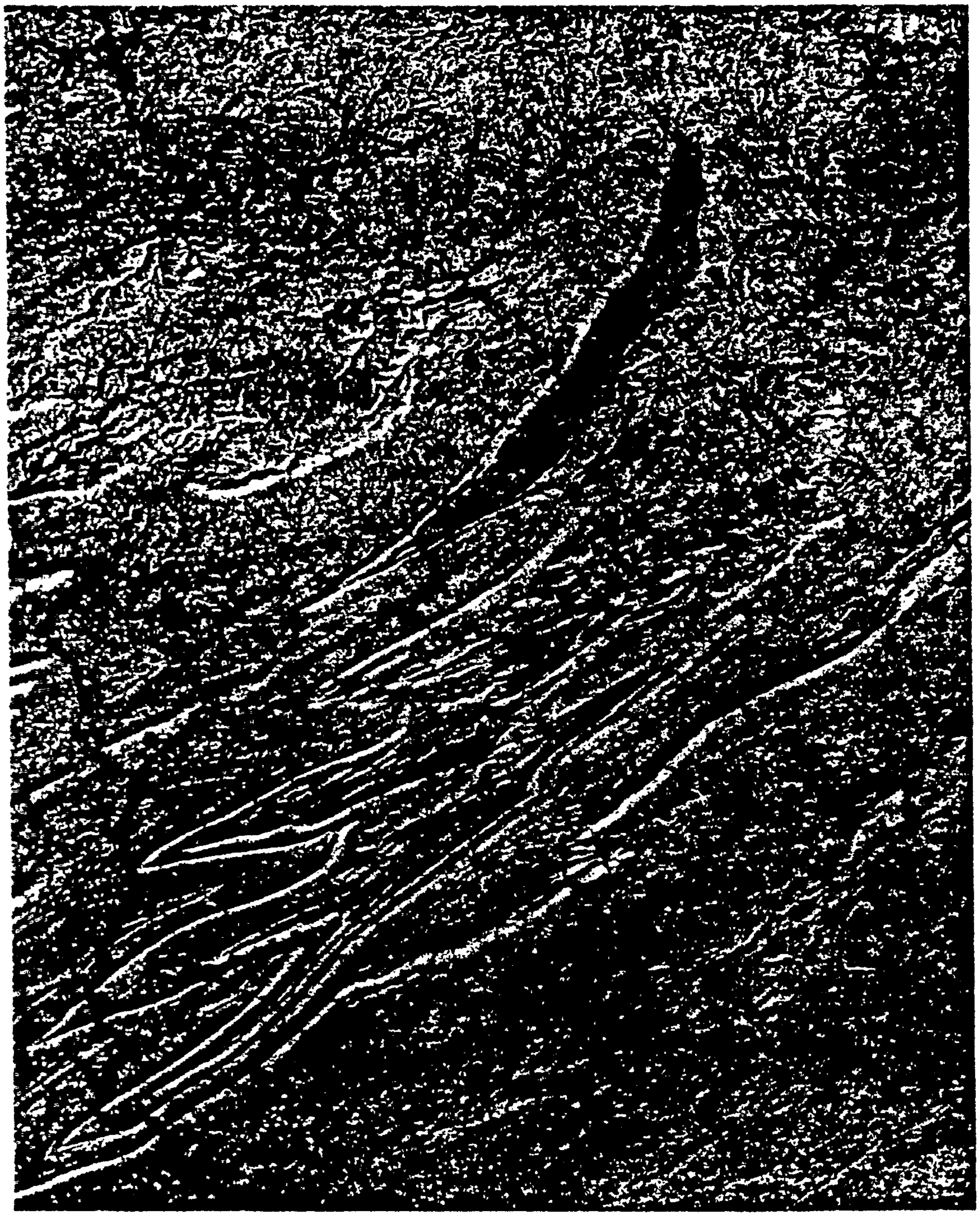

FIG. 2 LANDSAT IMAGE OF THE ANTHRACITE REGION OF NORTHEASTERN PENNSYLVANIA

74-144

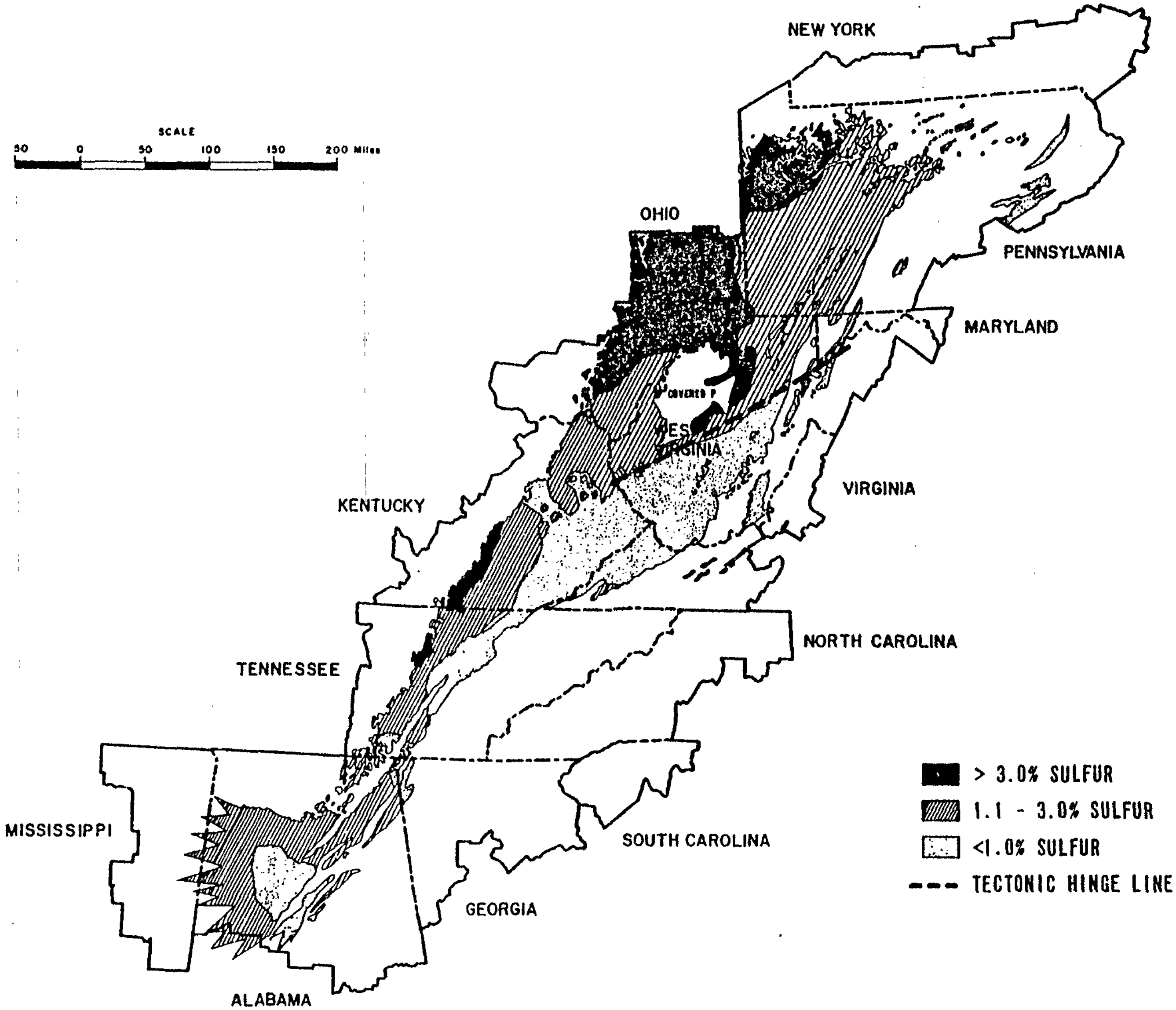

FIGURE 3 TECTONIC HINGE LINE SUPERIMPOSED UPON THE GENERALIZED SULFUR CONTENT MAP OF APPALACHIAN COALS

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deposition in western Pennsylvania, being subjected to greater marine influence, become more sulfurous.

In the Anthracite Region the coals are the most persistent lithologic units. The strata between coal seems commonly exhibit abrupt lateral changes in thickness and lithology. Because of these two factors, correlations are all based on the coal seams and special care was taken, particularly in the Northern Field to correlate seam data from colliery to colliery.

Maximum thickness of the Pennsylvanian rocks is approximately 4,900 feet[19] and is preserved in the synclines of the Southern Field near Pottsville. The sequence thins to the northwest to a maximum of 2,600 feet in the Western Middle Field south of Shamokin, a maximum of 2,200 feet in the Northern Field near Wilkes Barre, and less than 2,000 feet thick in the deepest part of the Eastern Middle Field near Hazleton. The lower part of the sequence thins the most to the northwest and the upper part of the sequence has been eroded. These factors lend credence to the hypothesis of narrow trough - like deposition during the early Pennsylvanian and a more extensive platform type beginning in Allegheny time.

Pedlow[16] has proposed a lithofacies model based on diachronous shifting of depositional environments to explain the northward thinning of the Pottsville conglomerate, Mauch Chunk Red beds, and Pocono sandstone. Three fundamental lithofacies are recognized in the Anthracite basins classified according to depositional environment. These include alluvial plain, delta plain, and tidal flat. In the lower regressive Pottsville sequence an alluvial plain depositional environment grades northward into the tidal flat environment of the Mauch Chunk Red beds. In the upper Post-Pottsville transgressive sequence an alluvial plain depositional environment grades northward to a lower delta plain.

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1.4.2 Stratigraphy. Stratigraphic correlation of the Pennsylvanian rocks of the Anthracite Region generally follows the scheme outlined in Table 2. Absolute correlation with the bituminous coal fields of Western Pennsylvania, Maryland, and West Virginia has not been established. Tentative relative correlation, however, is indicated in the table.

The coal bearing Pennsylvanian rocks are divided into two formations, the lower Pottsville formation and the overlying Llewellyn formation.

TABLE 2 THE STRATIGRAPHIC COLUMN IN THE ANTHRACITE REGION

74-144

SYSTEM	SERIES: STUDY AREA	SERIES: EASTERN U.S.	FORMATION	MEMBER	COAL SEAMS
EROSION SURFACE					SEE TABLES 4,5,6, AND 7
PENNSYLVANIAN	MIDDLE AND UPPER	CONEMAUGH ? ALLEGHENY	LLEWELLYN FORMATION		
	?				
	MIDDLE	KANAWHA	POTTSVILLE FORMATION	SHARP MOUNTAIN	
	LOWER	? LEE		SCHUYKILL	
				TUMBLING RUN	
MISSISSIPPIAN AND PENNSYLVANIAN	UPPER MISSISSIPPIAN AND LOWER PENNSYLVANIAN		MAUCH CHUNK FORMATION	UPPER MEMBER	

The Pottsville formation is of early and middle Pennsylvanian age and ranges in thickness from less than 100 feet in the Northern Field to more than 1400 feet in the Southern Field where it becomes an important coal producing formation. The Pottsville is the chief ridge former and is responsible for the steep escarpment around the Anthracite fields. The lithology is that of a quartz pebble and cobble conglomerate and quartzose sandstone interbedded with lesser amounts of siltstone, shale, and coal. It is subdivided into three members in the Southern and Western Middle Fields where it attains maximum thickness. The Pottsville formation contains as many as 11 coal beds in the western part of the Southern Field, five coal beds in the western part of the Western Middle Field, only one bed in parts of the Eastern Middle Field, and no coal beds in the Northern Field where the Pottsville formation has thinned to less than 100 feet. The Pottsville coals are thickest in the western parts of the Southern and the Western Middle Fields.

The Llewellyn formation is of Middle and Late Pennsylvanian age and includes all consolidated rock above the Pottsville formation. It is truncated by an erosion surface and overlain by Quaternary alluvial and glacial deposits. These glacial deposits bear particular significance to the subsidence problem in the Northern Anthracite Field due to the presence of a buried glacial valley.

The Llewellyn formation contains most of the coal seams of the region and is composed predominantly of conglomeratic sandstone, quartzose sandstone and siltstone with lesser amounts of conglomerate, carbonaceous shale, and coal. The maximum thickness of formation is distributed as shown in Table 3.

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TABLE 3 MAXIMUM THICKNESS DISTRIBUTION OF LLEWELLYN FORMATION 74-144	
FIELD	LLEWELLYN FORMATION THICKNESS
NORTHERN	2,200 FEET
EASTERN MIDDLE	LESS THAN 1,500 FEET
WESTERN MIDDLE	1,900 FEET
SOUTHERN	3,500 FEET

The Llewellyn formation can grossly be divided into three general lithologic members. These consist of a lower and upper coarse grained, darker hued sandstone and conglomeratic sandstone with interbedded dark sandstone, siltstone and shale. The middle sequence consists of lighter hued fine to medium grained sandstone, siltstone, and shale. Although there are more than 50 coal seams in the southern part of the region and more than 30 coal seams in the Northern Field a lesser number have enough lateral distribution to achieve major importance as regional seams. The lower coarse grained sequence of the Llewellyn formation generally contains eight persistent coal seams. The Buck Mountain and the Mammoth coals of the Southern, Western, and Eastern Middle Fields and the Red Ash and Baltimore Coals of the Northern Field are the most extensively mined coal beds of the region. The Middle Llewellyn sequence contains some 15 persistent beds of coal and the upper coarse grained sequence, where present, contains some five or more persistent coal beds. Tables 4, 5, 6, and 7 list in stratigraphic sequence, the major coal seams for each of the four fields giving the generally accepted name of the coal seam and the various synonyms used in the different collieries.[10] A seam code used in the data collection and modeling effort is included and discussed in Chapter II. Extensive correlation of seams was carried out in the Northern Field carrying the work of Bergin and Robertson[7] from the Wyoming into the Lackawanna Valley. These correlations are included in tables in section 2.4 of this report.

TABLE 4 STRATIGRAPHIC COAL SEAM SUCCESSION, SEAM CODES, AND SYNONYMS, NORTHERN ANTHRACITE FIELD

74-144

SEAM CODE	LLEWELLYN FORMATION (Pl) 2200 FT. MAX. (010-062)
010	NO. 8
012	NO. 7 (NO. 2, NO. 1 (LUZERNE CO.))
014	NO. 6 (NO. 3, NO. 2 (LUZERNE CO.))
016	NO. 5 (NO. 4, NO. 3 (LUZERNE CO.))
018	NO. 4 (NO. 5, NO. 3 (LUZERNE CO.))
020	NO. 3 (NO. 6, NO. 5, NO. 2, TOP GEORGE (LUZERNE CO.))
022	NO. 2 (TOP SNAKE ISLAND (LUZERNE CO.))
024	SNAKE ISLAND (NO. 1, GEORGE (LUZERNE CO.))
026	ABBOT (ORCHARD (LUZERNE CO.), EIGHT-FOOT (LACKAWANNA CO.))
028	KIDNEY (MILLS, BOWKLEY (LUZERNE CO.), FIVE-FOOT (LACKAWANNA CO.))
030	HILLMAN (FOUR-FOOT, THIRTY INCH (LACKAWANNA CO.))
032	UPPER STANTON (TOP DIAMOND, TOP ORCHARD, TOP STANTON, ROCK, TOP FIVE-FOOT (LUZERNE AND LACKAWANNA CO.))
034	DIAMOND OR LOWER STANTON (LANCE, BALTIMORE, STANTON, BOTTOM DIAMOND, FIVE-FOOT, ORCHARD BOTTOM FIVE-FOOT, FOUR-FOOT, TOP FIVE-FOOT (LUZERNE AND LACKAWANNA CO.))
036	UPPER LANCE (ROCK, TOP ROCK, TOP CHECKER, COOPER, TOP FORGE, TOP FOUR-FOOT (LUZERNE AND LACKAWANNA COUNTIES))
038	LOWER LANCE (ROCK, BOTTOM ROCK, BOTTOM CHECKER, FORGE, FIVE-FOOT, SUMP, LANCE, STANTON, CHECKER (LUZERNE AND LACKAWANNA CO.))
040	UPPER PITTSTON (TOP BALTIMORE, UPPER BALTIMORE, TOP TWIN, COOPER, CHECKER, TOP PITTSTON, BIG, TOP BIG, PITTSTON, TOP GRASSY (LUZERNE AND LACKAWANNA CO.))
042	LOWER PITTSTON (BOTTOM BALTIMORE, LOWER BALTIMORE, PITTSTON, TWIN, BENNETT, BOTTOM TWIN, RED BENNETT, SIX FOOT, BIG, BOTTOM BIG, GRASSY (LUZERNE AND LACKAWANNA CO.))
044	UPPER SKIDMORE (NEW COUNTY, CHECKER, TOP ELEVEN-FOOT, TOP MARCY (LUZERNE AND LACKAWANNA CO.))
046	MIDDLE SKIDMORE (TOP MARCY, NEW COUNTY, ETC.)
048	LOWER SKIDMORE (BOTTOM NEW COUNTY, MARCY, SKIDMORE, FORGE, CHECKER, TWIN, ELEVEN-FOOT, TOP SKIDMORE, BOTTOM ELEVEN-FOOT, ROSS, NINE-FOOT, NEW COUNTY, (LUZERNE AND LACKAWANNA CO.))
050	UPPER ROSS (TOP ROSS, TWIN, MIDDLE SKIDMORE, BOTTOM SKIDMORE, TOP CLARK, THREE-FOOT, CLARK, (LUZERNE AND LACKAWANNA CO.))
052	MIDDLE ROSS (BOTTOM SPLIT, TOP ROSS, BOTTOM SKIDMORE, MIDDLE CLARK, (LUZERNE AND LACKAWANNA CO.))
054	LOWER ROSS (ROSS, BOTTOM ROSS, ROSS SPLIT, TOP ROSS, THREE-FOOT, BOTTOM CLARK, CLARK, (LUZERNE AND LACKAWANNA CO.))
056	UPPER RED ASH (DUNMORE NO. 1, TOP RED ASH, CHAUNCEY, ROSS, BOTTOM ROSS, BABYLON, STARK, NIGGER (LUZERNE AND LACKAWANNA CO.))
058	MIDDLE RED ASH (DUNMORE NO. 2, TOP LEE, FIFTH, FIVE-FOOT (LUZERNE AND LACKAWANNA CO.))
060	LOWER RED ASH (DUNMORE NO. 3, RED ASH, LEE, BOTTOM RED ASH, SIXTH (LUZERNE AND LACKAWANNA CO.))
062	COAL BED A (DUNMORE NO. 4, "A", CHINA (LUZERNE AND LACKAWANNA CO.))
	POTTSVILLE FORMATION (Pp) ·100 FEET (070-079)
	SHARP MOUNTAIN MEMBER (070-074)
071	CAMPBELLS LEDGE (DURYEA, LUZERNE CO.)
080	MAUCH CHUNK FORMATION (Mm) 5-1000 FEET
085	POCONO FORMATION (Mp) 600 FEET
090	CATSKILL FORMATION (DCK)

NOTE: MAX. THICKNESS OF PENNSYLVANIAN ROCKS APPROX. 2200 FEET

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TABLE 5 STRATIGRAPHIC COAL SEAM SUCCESSION, SEAM CODES, AND SYNONYMS, WESTERN MIDDLE ANTHRACITE FIELD

74-144

SEAM CODE	
	LLEWELLYN FORMATION (Pl) 1900 FT. MAX. (010-068)
030	NO. 20 RABBIT HOLE
032	NO. 19 TUNNEL
034	NO. 18 PEACH MOUNTAIN
036	LITTLE TRACY NO. 17
040	TRACY (NO. 16, NO. 14)
046	LITTLE DIAMOND NO. 15
048	DIAMOND (NO. 14, NO. 13)
050	LITTLE ORCHARD NO. 13 (U. SPLIT TWIN)
052	ORCHARD (NO. 12 (L. SPLIT TWIN))
T54	PRIMROSE (UPPER SPLIT) NO. 11 (UPPER SPLIT) NO. 11 1/2
B54	PRIMROSE (LOWER SPLIT) NO. 11 (LOWER SPLIT)
T56	ROUGH (NO. 10 1/2, HOLMES)
056	HOLMES (NO. 10)
T58	LOWER FOUR-FOOT (NO. 9 1/2, MAMMOTH TOP SPLIT)
058	MAMMOTH TOP SPLIT (NO. 9) } MAMMOTH COAL ZONE (238-240)
060	MAMMOTH MIDDLE SPLIT (NO. 8 1/2, NO. 8) } MAMMOTH COAL ZONE (238-240)
062	MAMMOTH BOTTOM SPLIT (NO. 8, NO. 7 1/2) } MAMMOTH COAL ZONE (238-240)
064	SKIDMORE (NO. 7)
066	SEVEN FOOT (NO. 6)
068	BUCK MOUNTAIN (NO. 5)
	POTTSVILLE FORMATION (Pp) 860-1250 FEET (070-089)
070	COAL D
072	COAL C
074	COAL B
076	COAL A
078	LYKENS VALLEY NO. 4 (LYKENS VALLEY NO. 2)
090	MAUCH CHUNK FORMATION (Mm) 3000 FT.
096	POCONO FORMATION (Mp)
098	CATSKILL FORMATION (DCK)

NOTE: MAX. THICKNESS OF PENNSYLVANIAN ROCKS 2600 FT.

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TABLE 6 STRATIGRAPHIC COAL SEAM SUCCESSION, SEAM CODES, AND SYNONYMS, SOUTHERN ANTHRACITE FIELD

74-144

SEAM CODE	LLEWELLYN FORMATION (Pl) 3500 FT. MAX. (010-068)	
012	NO. 29	
014	NO. 28	
016	NO. 27	
018	NO. 26	
020	NO. 25	
022	NO. 24	
024	NO. 23 1/2	
026	NO. 22	
028	FAUST (NO. 21)	
030	RABBIT HOLE (NO. 20)	
032	TUNNEL (NO. 19)	NO. 19T T32 NO. 19B B32
034	PEACH MOUNTAIN (NO. 18)	NO. 18T T34 NO. 18B B34
036	LITTLE TRACY (NO. 17)	UPPER FOURFOOT (NO. 16 1/2) 038 LITTLE CLINTON (NO. 15 1/2) 042 CLINTON (NO. 15 1/4) 044
040	TRACY (NO. 16) (SALEM, TUNNEL)	
046	LITTLE DIAMOND (NO. 15)	
048	DIAMOND (NO. 14)	
050	LITTLE ORCHARD (NO. 13) (TWIN U. SPLIT)	
052	ORCHARD (NO. 12) (TWIN L. SPLIT)	
054	PRIMROSE (NO. 11)	NO. 11T T54 NO. 11B B54
056	HOLMES (NO. 10)	
058 060 062	MAMMOTH TOP SPLIT (NO. 9) MAMMOTH MIDDLE SPLIT (NO. 8 1/2) MAMMOTH BOTTOM SPLIT (NO. 8)	MAMMOTH COAL ZONE (058-062)
064	SKIDMORE (NO. 7)	
066	SEVENFOOT (NO. 6)	
068	BUCK MOUNTAIN (NO. 5)	
	POTTSVILLE FORMATION (Pp) >1400 FT. MAX. (070-089)	
070	LITTLE BUCK MOUNTAIN (NO. 4, "A")	SHARP MOUNTAIN MEMBER (Pps) (070-074)
072	SCOTTY STEEL NO. 3	
074	SCOTTY STEEL NO. 2	
076	LYKENS VALLEY NO. 1	SCHUYLKILL MEMBER (Ppc) (076-080)
078	LYKENS VALLEY NO. 2	
080	LYKENS VALLEY NO. 3	
082	LYKENS VALLEY NO. 4	TUMBLING RUN MEMBER (Ppt) (082-088)
084	LYKENS VALLEY NO. 5	
086	LYKENS VALLEY NO. 6	
088	LYKENS VALLEY NO. 7	
090	MAUCH CHUNK FORMATION (Mm) 3500 ± FEET (090-094)	
091	UPPER MEMBER (PMmu)	
092	MIDDLE MEMBER (Mmm)	
096	POCONO FORMATION (Mp)	
098	CATSKILL FORMATION (DCK)	

NOTE: MAX. THICKNESS OF PENNSYLVANIAN ROCKS APPROX. 4900 FT.

ORIGINAL

(red)

TABLE 7 STRATIGRAPHIC COAL SEAM SUCCESSION, SEAM CODES, AND SYNONYMS, EASTERN MIDDLE ANTHRACITE FIELD

74-144

SEAM CODE	LLEWELLYN FORMATION (Pl) ~1500 FEET MAX (010-068)
040	TRACY
046	LITTLE DIAMOND
T48	DIAMOND NO. 2
B48	DIAMOND NO. 1
050	LITTLE ORCHARD
052	ORCHARD
054	PRIMROSE
058	MAMMOTH (058-062)
064	SKIDMORE (WHARTON)
066	SEVEN FOOT (GAMMA)
068	BUCK MOUNTAIN
	POTTSVILLE FORMATION (Pp) (070-089)
070	LITTLE BUCK MOUNTAIN (ALPHA)
076	LYKENS VALLEY (NO. ?)
	MAUCH CHUNK FORMATION (Mm)
096	POCONO FORMATION (Mp)
098	CATSKILL FORMATION (DCK)

NOTE: MAX. THICKNESS OF PENNSYLVANIAN ROCKS ~2000 FT.

1.4.3 Structure. The tightly folded and faulted strata of much of the Anthracite Region reflects the proximity of the area to the axis of deformational intensity in the Appalachian Highlands. Two structural generalizations prevail and have been mentioned previously as they affect topographic expression. These are the synclinorial aspect of the Northern, Western Middle, and Southern Fields and occupance, by the Eastern Middle Field, of the crestal area of an anticlinorium.

Folding is tighter and asymmetrically shaped in the western and southern parts of the region and more open and symmetrical in the Northern Field.

Faulting is prevalent in the region and consists of low-to-high angle thrust faults, bedding plane faults, and tear faults. Displacements along the faults are greatest in the Southern field reaching one mile on the low-angle thrusts and 3,000 feet on the high-angle thrusts. Some of the faulting and fracture lineations of the Anthracite Region can be seen on the LANDSAT imagery. A detailed remote sensing investigation of the Northern Anthracite field was conducted under Contract EER-123 by Earth Satellite Corporation. In lieu of any detailed remote sensing analysis for the other 3 fields a cursory lineation analysis was performed by HRB-Singer personnel on the ERTS imagery with results as shown in Figure 4.

1.4.4 Post-Llewellyn Deposits - The Buried Glacial Valley. The geological history of the Anthracite Fields has played a significant role in creating the subsidence problems encountered today. The glacial erosional and depositional processes have strongly affected a part of the region exercising their greatest effect on the Northern Anthracite Field.

The Wyoming Valley is particularly vulnerable to surface subsidence resulting from mining and natural non-mining related events. The relatively recent geological history

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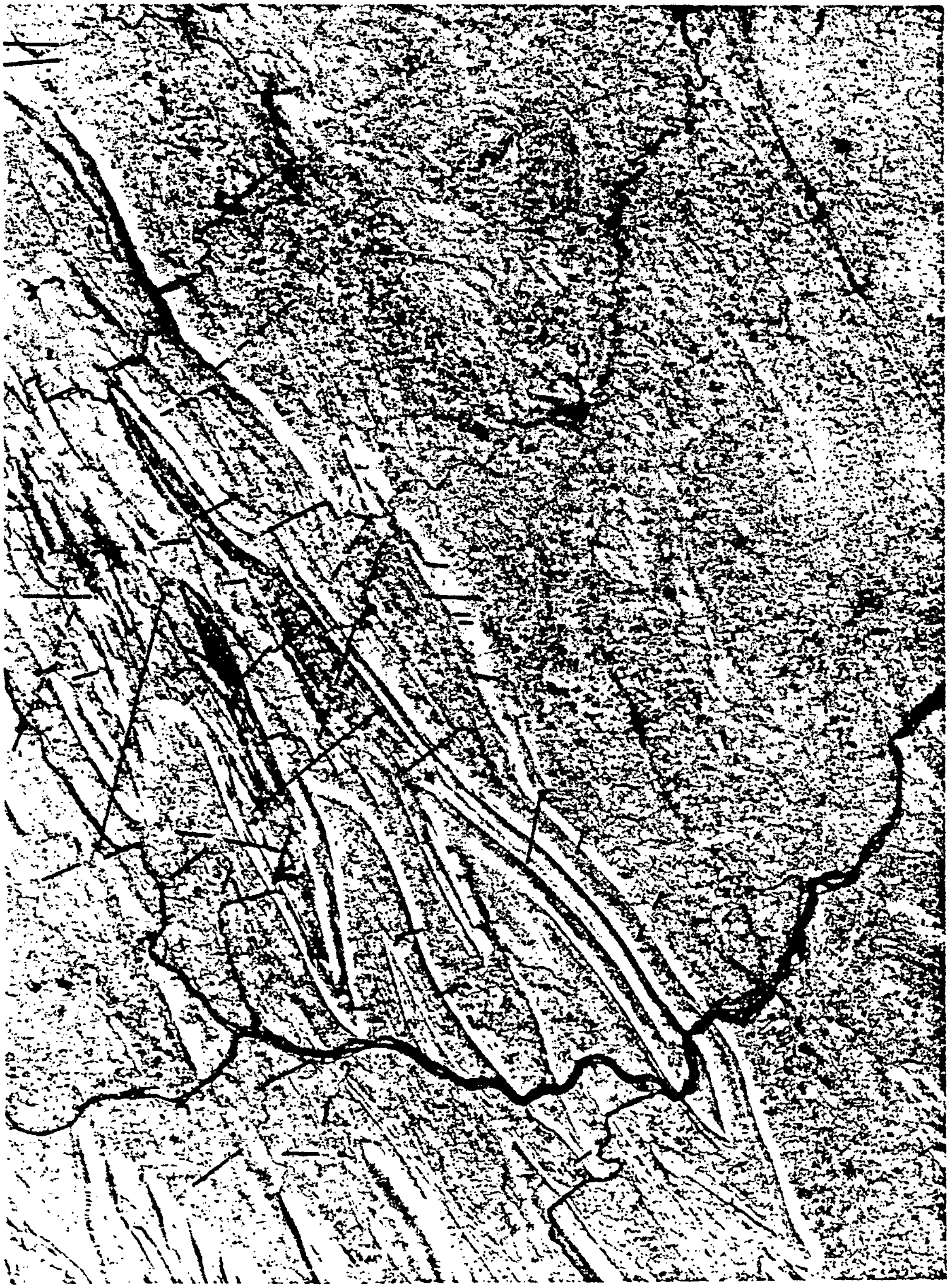

FIG. 4 LANDSAT IMAGERY LINEATIONS IN THE SOUTHERN ANTHRACITE REGION

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together with the physical properties of the anthractie coal bearing formations have combined to yield a unique setting upon which has been superimposed the subsidence problems. The Wyoming Valley, being contained within the northernmost of the four anthracite fields was subjected to the greatest erosion by continental glaciation during Illinoian and Wisconsin time. The canoe-shaped structure of this synclinorium trends in a northeast/southwest direction and presented a formidable obstacle to the southeastward moving ice sheet. Ice movements were diverted southwestward parallel to the long axis of the structure and the softer and easily fractured beds of the coal bearing strata (Llewellyn formation) were deeply eroded. Subsequent filling of the gouged valley by glacially transported material during and after the ice retreat has left the present situation of a "buried glacial" or "hidden valley." The presence of this structure has presented a dual hazard in terms of surface subsidence in the Wyoming Valley. The uncertain configuration of this buried valley makes coal mining under and along its margins hazardous and constantly presents the possibilities of sudden and catastrophic cave-ins and inundations by water and water-saturated sediments. These cave-ins are manifested on the surface by subsidence of the land. The heterogeneous nature of the unconsolidated valley fill, in the sense that it is composed of materials of both a stratified and unstratified nature, make for unstable natural conditions that are largely dependent on the amount of water contained as ground water and the amount available from the surface. The valley fill becomes particularly unstable during times of surface flooding. Natural subsidence is likely to occur under such conditions.

The presence of glacially transported materials far up on the slopes of the Wyoming Valley also presents potentially unstable conditions under periods of stress such as might be encountered during heavy rainfalls. This is compounded by the extensive areas of surface strippings and waste piles.

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In addition to these hazards directly or indirectly related to the glacial history of the region, the almost unparalleled destruction of the coal strata by man has left large areas unprotected and subject to further destruction by fire. The many areas of the anthracite region currently identified on HRB-Singer, Inc. thermal imagery to be burning outcrop and mine waste embankment fires all add to the complexity of subsidence problems. It is conceivable that mine fires acting over long periods of time can produce subsidence on a scale comparable to that produced by coal mining itself.

The remaining three anthracite fields remain virtually unaffected by direct glaciation lying for the most part south of all of the terminal moraines (see Geologic map of Pennsylvania, Gray, 1960).

ORIGINAL
(red)

2. APPROACH

2.1 DISCUSSION OF SUBSIDENCE

2.1.1 Introduction. The ensuing discussion is extracted in part from a draft of an article on subsidence and ground movement prepared by Dr. Robert Stefanko, Professor of Mining, at the Pennsylvania State University. The article was subsequently published in the Mining Engineers Handbook.[17] The discussion assesses the significant parameters of subsidence.

There are many factors affecting the stability of an underground mine, (see Figure 5). The span (W) is undoubtedly one of the most important factors contributing to roof failure. If the mined area is relatively small, the overlying rock strata can bridge across the opening and little if any movement or convergence of top and bottom will occur. However, as the span increases, a point is reached where the stress in the overlying rock strata exceeds a given strength value of the rock in the mine structure and the top breaks. If the span is limited to some subcritical value ($-W_c$) and/or is located at great depth (D) from the surface, a pseudoarch will form achieving stability before rupture occurs to the surface. The boundary of this arch is thought to approximate an ellipse in form with the major axis vertical and equal to four times W, although little field research has been conducted to substantiate this theory. If however, span width is increased to some critical value (W_c) and/or the same span is created at another horizon in a shallower seam, the overlying strata will progressively rupture to the surface and form the characteristic subsidence trough (Fig. 5).

In subsidence the surface area affected is much greater than the area of the seam extracted. To define this area, an angle is drawn between a vertical line from the edge of the

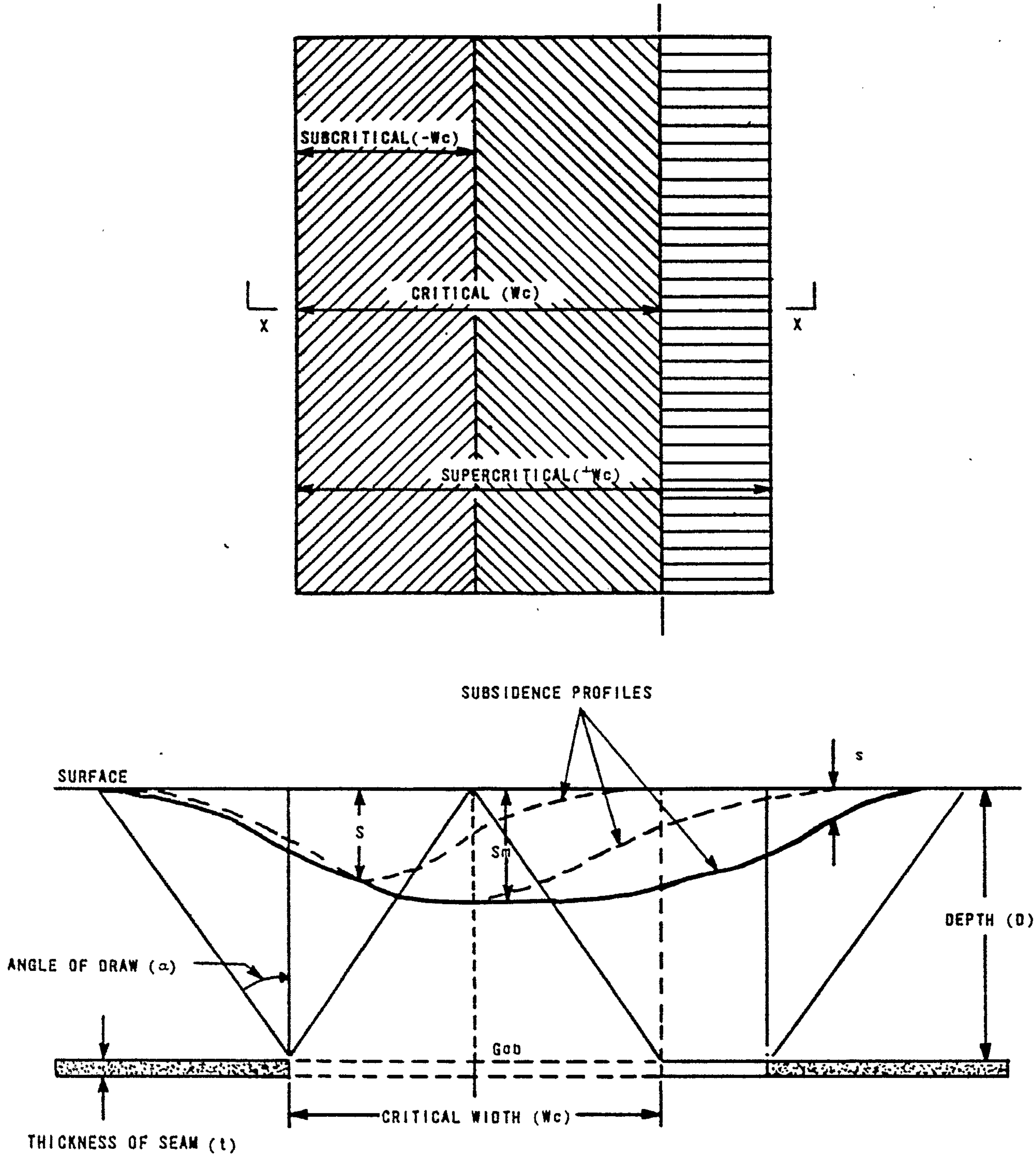

FIGURE 5 EFFECTS OF WIDTH OF EXTRACTION ON SURFACE SUBSIDENCE.(1)

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seam opening and another line extended to a point at which (red) zero subsidence occurs and is called the angle of draw (α). This angle has been found to be about 35^{o} in Europe but since the subsidence effect is so small at any point beyond a 25^{o} angle, this latter figure may be considered the practical limit of subsidence. Furthermore, indications are that the angle of draw varies with depth and nature of the strata.

The width of the excavation applies to any complex mining system of entries, rooms and longwalls as long as the seam has been fully extracted and the width represents the distance from one solid rib to another. The amount of vertical displacement varies from point to point on the surface (s), but the maximum subsidence for a given trough occurs at the center (S). The latter value may not be equal to the maximum possible subsidence (S_m) which occurs only if a critical or supercritical ($+W_c$) width has been exceeded.

Since substantial surface damage can result when subsidence occurs, the factors affecting the amount and type of ground movement must be recognized. These factors include thickness and properties of the seam, angle of draw, width of excavation, depth and type of overburden, inclinations of strata and surface, and the amount of support left in the gob. In Europe, high population densities, high development costs due to excessive depth and poor natural conditions, the mining of superposed seams and more stringent subsidence damage liability have led to a comprehensive evaluation of subsidence and its damaging effects. A great deal of empirical information has been gathered to identify the factors leading to subsidence in order to optimize mining methods to minimize the incidence of damage.

2.1.2 Critical Area. The concept of a critical width of extraction (in reality critical area) is indisputable today and merits brief discussion. Assuming an infinite length of working panel (a panel length in excess of 1.4 of the depth of mining actually fulfills this criterion), a critical width (W_c) of extraction for a given depth (D) has been found at which the subsidence at the bottom of the surface trough in the center has a maximum possible value (S_m). Subcritical widths of extraction ($-W_c$) produce a trough subsidence (S) less than (S_m) while a supercritical value ($+W_c$) creates an expanding flat trough with a maximum value equal to S_m, Figure 5.

Precision leveling of surface subsidence stations in Europe has permitted a graphical illustration of the relationships of W, D, and S. Maximum subsidence of a trough can be expressed in terms of percentage of seam thickness (S/t). The subsidence development curve in Figure 6 has been found to be applicable for British conditions. This is a mean subsidence curve based on measurement made by the National Coal Board over 157 coal mines from 100 to 2600 ft. deep, with seams ranging in thickness from 2-18 ft. and inclined up to 25^o with the horizontal, with widths varying from 100 to 1500 ft. and width/depth ratios from 0.05 to 4.0. It is apparent that as long as the W/D ratio is less than 0.25, subsidence (and inferentially damage) is negligible. Furthermore, it is apparent from the figure that a W/D ratio of 1.2 total subsidence has been achieved, which for total caving exceeds 90% of the seam thickness. Further mining beyond this point merely expands the flat portion of the trough, the maximum value of subsidence remaining constant. In Western Pennsylvania surface subsidence was found to be 60% of seam thickness over an 84 inch thick coal bed located 313 to 345 ft. deep.

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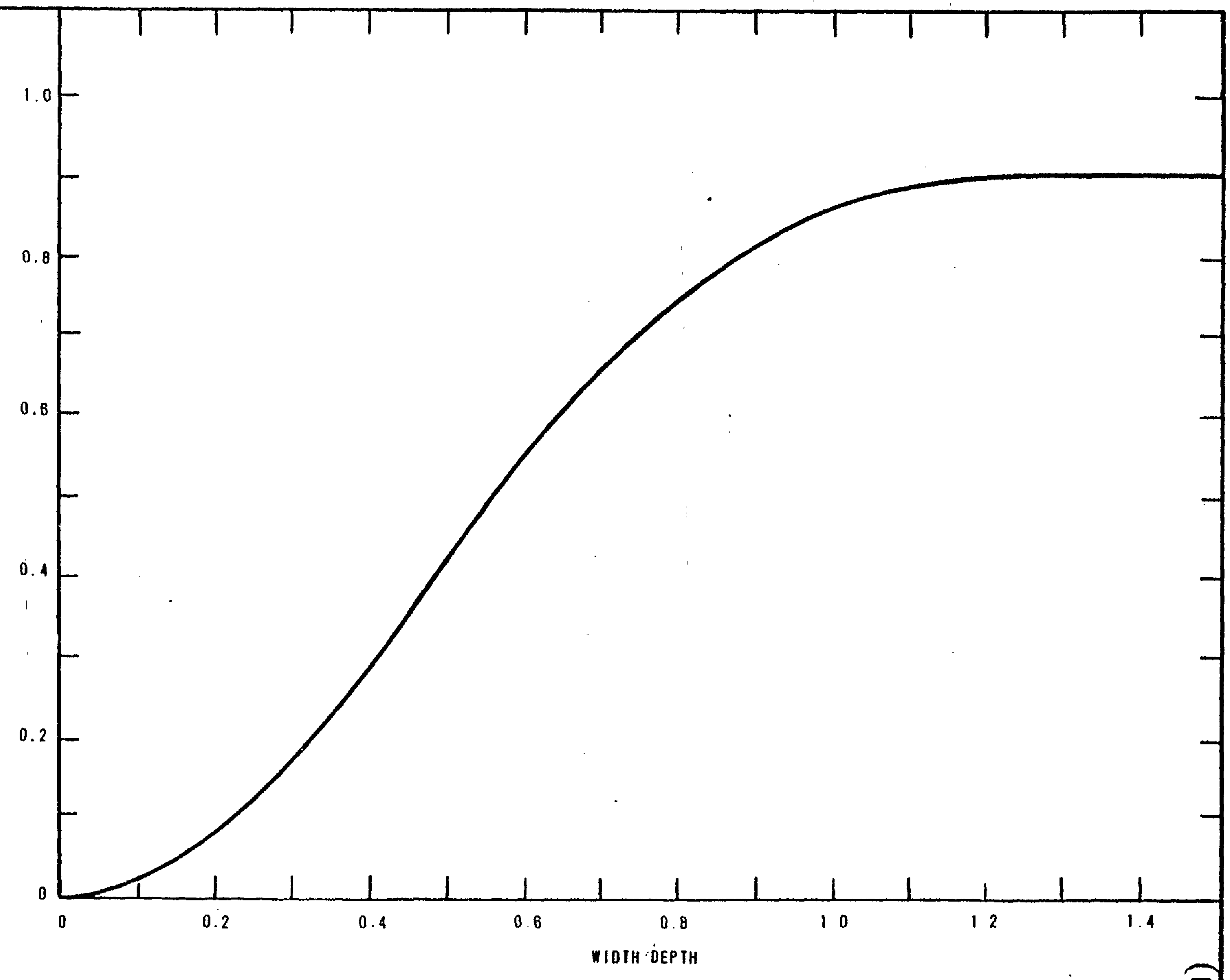

FIGURE 6 SUBSIDENCE AS A FUNCTION OF W/D FOR FULL CAVING.[1] MEAN SUBSIDENCE CURVE
S - SUBSIDENCE t SEAM THICKNESS

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Each subsiding point on the surface (Figure 7) has a horizontal component as well as a vertical one. As the points move toward the center of the trough differentially, a portion of the surface is in tension while another portion is in compression. The neutral or transition point is found to occur just inside the gob area close to the rib of the opening near critical width and is also found to be the half-point of subsidence (S/2). For Subcritical widths, this point appears over the solid rib while for supercritical width it appears further in the gob. The maximum tensile and compressive strains have been found to occur when the width to depth ratio (W/D) is approximately equal to one half the critical width ($W_c/2$). The angle included between a horizontal line and another drawn from the edge of the working to a point on the surface subject to maximum tensile strain is defined as the angle of break.

Figure 7 reveals that the W/D ratio alone may not be the most important consideration in minimizing building damage. Two seams with the same thickness may be mined at different depths but have identical W/D ratios and thus have the same amount of vertical subsidence. However, because the curvature is greater with the shallower seam, the tensile strain will be higher and greater damage can be anticipated in a given building. Looking carefully at this figure, it can be intuitively reasoned and proved mathematically that a thicker seam for an otherwise identical condition would create greater curvature and lead to increased tensile strains and subsequent damage. Thus it can be stated unequivocably that the greatest damage potential lies with the mining of thicker seams near the surface. The failure to recognize this has resulted in serious damage or very ineffective damage control measures. It would be poor engineering to accept the corollary of this, however, that greater mistakes can be tolerated at a greater depth with thinner seams without disaster.

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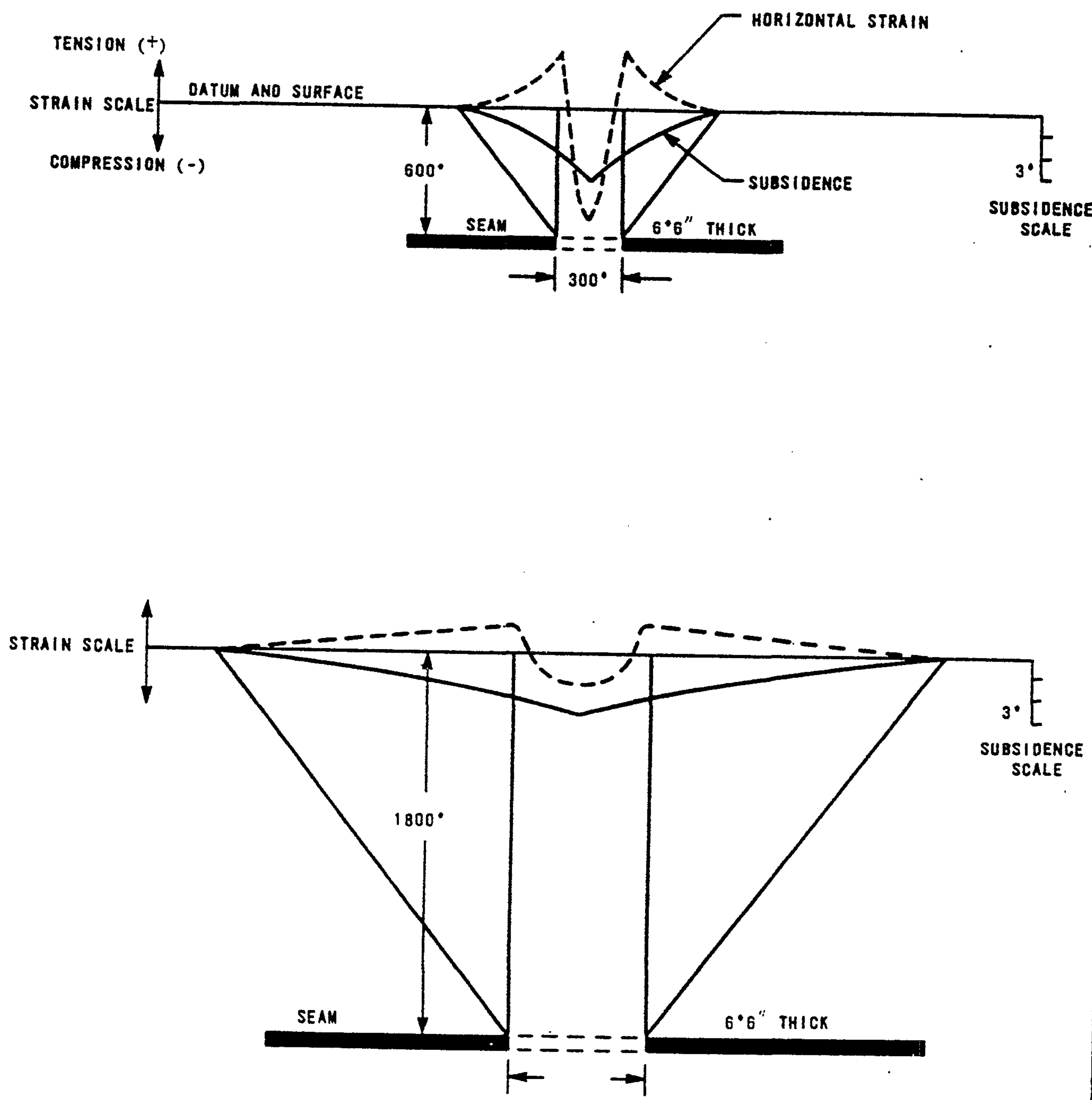

FIGURE 7 EFFECT OF SEAM DEPTH ON GROUND CURVATURE AND STRAIN UNDER IDENTICAL W/D CONDITIONS.[1]

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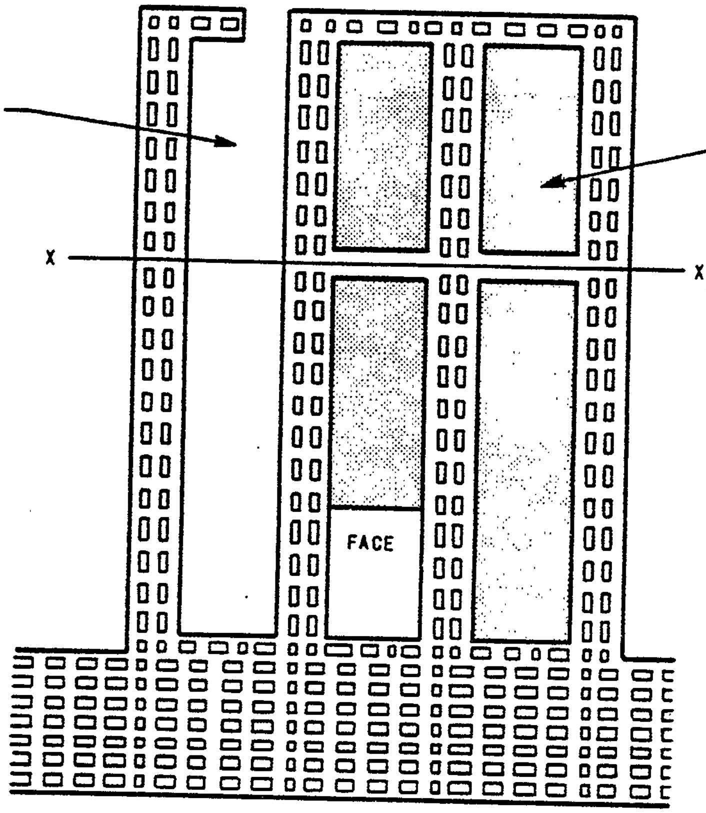
To this point in the discussion only a completely unsupported span has been considered. In mining practice however, the pressure of small pillars as abutment piers within the unsupported area is the common case. The practical implication is revealed in Figure 8 which shows a typical longwall operation in central Pennsylvania. Here one of the important seams mined is approximately 44 in. thick and lies 700-1000 ft. deep. A longwall face 600 ft. wide is blocked out by a pair of three 18-ft. wide entries on 70 ft. centers. Obviously, the first panel mined would provide a subcritical width of excavation and full subsidence would not be realized. With the mining of a second panel, however, a critical width would be achieved over the two panels. The presence of the two chain pillars from the previously mined panel would provide central support and maximum subsidence would not occur on the surface. Instead, a modified curve such as shown in Figure 8 would result. Studies abroad have revealed that 40% of normal subsidence would be expected in the center of the trough. In a continuing study in central Pennsylvania it has been found that the surface is being let down very slowly and uniformly and over a foot of subsidence already has been detected on the surface over chain pillars. It is impossible to predict the amount of subsidence over such small pillars although their yielding might prove very beneficial. The effect of small pillars in minimizing subsidence by maintaining stability is very unpredictable. Entering into the calculations are at least the following factors: depth, extraction ratio, pillar loading, height-to-width ratio of the pillar, size and shape of pillars, strength characteristics of the mineral and surrounding rock, wetness of workings and degree of pillar confinement.



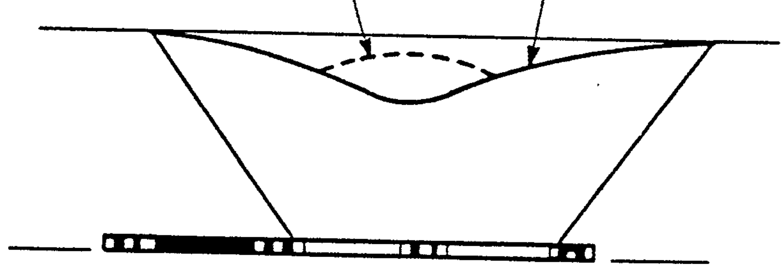


FIGURE 8 SURFACE SUBSIDENCE PROFILES OVER LONGWALL PANELS WITH AND WITHOUT CENTRAL CHAIN PILLARS

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2.2 SUBSIDENCE EVALUATION CRITERIA

2.2.1 Critical Parameters. The basis of critical parameter selection was the evaluation of historical data, experimental model studies and theoretical analysis both as reported in the literature and through personal communications.

Initially three basic types of data were reviewed in formulating parameter criticality. The first of these is physical/natural data reflecting endemic conditions and the influence of other natural phenomena. These parameters include the geology, hydrology, physiography, and meteorological aspects affecting each land area.

The influences due to these parameters may range from continuous and dynamic through static and quasi-passive depending on their temporal relationship to the subsidence development curve.

Structural and cultural influences form the second basic data type and include man made parameters ranging from initial mine portal and extraction techniques through present day loading effects created by urbanization. Many of these parameters are dynamic in nature and provide a continuum of interactions with the physical/natural parameters.

Social/Economic elements constitute the third basic type of data and refer to the social and economic characteristics present in each land area. The social elements pertain to the distribution characteristics of the population, while the economic elements refer to the composition of their resources and activities.

During the early stages of data source location and preliminary model development the list of possible parameters affecting or related to subsidence was narrowed.

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As data collection progressed and data sources became known and the types and reliability of these data established it became evident that certain parameters were critical to the determination of subsidence.

The final computerized data base was formulated to hold these specific parameters from which maximum subsidence and subsidence risk/potential could be calculated. In addition to location and seam code identification number the following twenty-three critical parameters include:

Seam Thickness	Width (Span)	Surface Elevation
Seam Depth	Collapse	Slope
Percentage Extraction	Backfill	Past Subsidence
Rock Cover	Lithology	No mining
Minimum Pillar Dimension	Condition	Flood Level
Minimum Pillar Area	Dip	Population
Rock Integrity	Pool Level	Real Estate Value
Year Last Mined	Soil Thickness	

Calculations made from these data values include maximum subsidence (S_{max}), Width to Depth ratio (W/D), Pillar Pressure, Pillar Width to Thickness ratio, and Pillar Width to Depth ratio.

These calculations and data are used by the computer model to classify each basic land area into subsidence risk/potential classes.

Each of the critical parameters is discussed in section 2.3.2 and data collection procedures in section 2.3.1. Computer modeling calculations are discussed in section 2.5.

2.2.2 Grid System. A primary requirement to represent the Anthracite Region in a workable, organized manner was to develop a base map reference system. Many considerations had to be taken into account to make this data base practical. Among them was the ability of the system to (a) provide adequate resolution, (b) be compatible with or easily convertible to existing data sources thereby facilitating data transfer and subsequent coding for computer location, correlation, and cross-correlation, and (c), provide for easy expansion of the system in terms of both serial coverage and applicability to related studies.

An initial consideration was the type and scale of map. During the early phases of data collection, many agencies visited were observed to be using the 7.5 minute series topographic quadrangle maps of the U.S. Geological Survey with a scale of 1:24,000. Many previous projects at HRB-Singer involving the Anthracite Region had proven the usefulness of these maps not only for their topography but for their natural and cultural features which are of special interest in this study. These factors in addition to the general familiarity of this map series to any potential user of the final output product led to the adoption of the 7 1/2 minute quadrangle as the base map.

The next decision involved the method of subdividing the quadrangle maps to achieve the objectives stated earlier. Two candidate systems seemed appropriate. One was to use the Universal Transverse Mercator Projection system. The advantages included the ability to read out directly from the maps the distance in meters on a north-south and east-west grid and also to make use of the grid system to enclose the segments or elements of territory to create a finite square area that would be the same over the entire region. A major disadvantage was that the grid system is not confined to the boundaries of the individual quadrangle maps but would generate some elements that would appear partially on two or more quadrangles. Also, without further subdivision the segments printed on the quadrangles would form an area of approximately 242 acres - somewhat too large for the resolution desired.

The system finally implemented employs the 1:24,000 (7 1/2') series of topographic maps but with subdivisions confined to each quadrangle into nine 2 1/2' sections (or rectangles) as marked on the maps and then further subdividing each section into a referenced 10 x 10 grid. Rectangular elements of approximately 1500 feet by 1160 feet or 40 acres are formed. The desired vertical and horizontal control required as well as the resolution necessary for the more developed urbanized areas can be maintained using this method. In addition, the base scale is compatible with much of the existing data for the area and the element breakdown provides for easy computer coding for location and correlation. Section 3.3.2 of this report contains the maps with this grid system superimposed. Figure 9 illustrates the identification system for each quadrangle down to the specific element size, i.e. Nanticoke Quadrangle, Section 9, Element C-8. Figure 10 shows the same element (hatched) to actual scale. This system, adopted for the entire study area, proved to be adequate and will be easy to further implement as additional work in the area or additional areas are brought into the system.

2.3 DATA COLLECTION FORMAT/PROCEDURES

2.3.1 Data Collection.

2.3.1.1 Preliminary Data Collection. The acquisition of information relevant to the critical parameters identified for subsidence potential classification while encompassing such a large geographical area as the Anthracite Region proved to be a task of major

IDENTIFICATION/GENERAL DATA

1. QUAD (7.5') NAN(ticoke) SECTION (2.5') 9 ELEMENT 8/C

COUNTY LUZERNE TOWNSHIP SLOCUM BORO/MUNICIPALITY ______

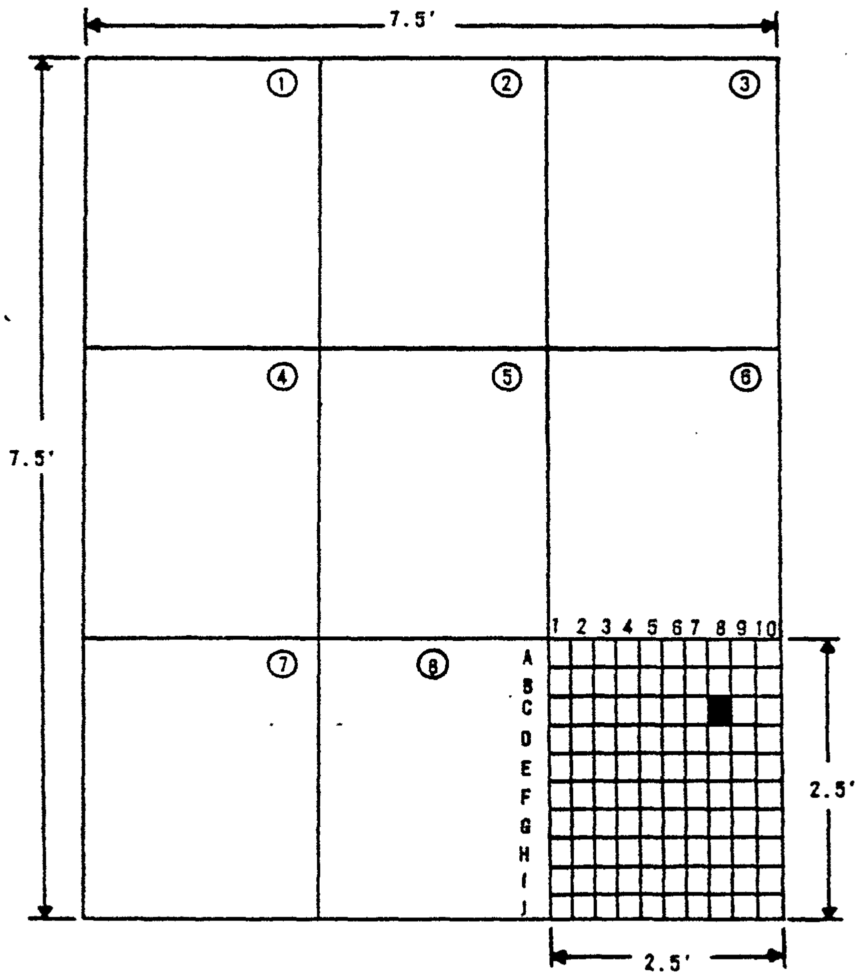

FIGURE 9 IDENTIFICATION AND GRID SYSTEM

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QUAD NAN SECTION 9 ELEMENT 8/C

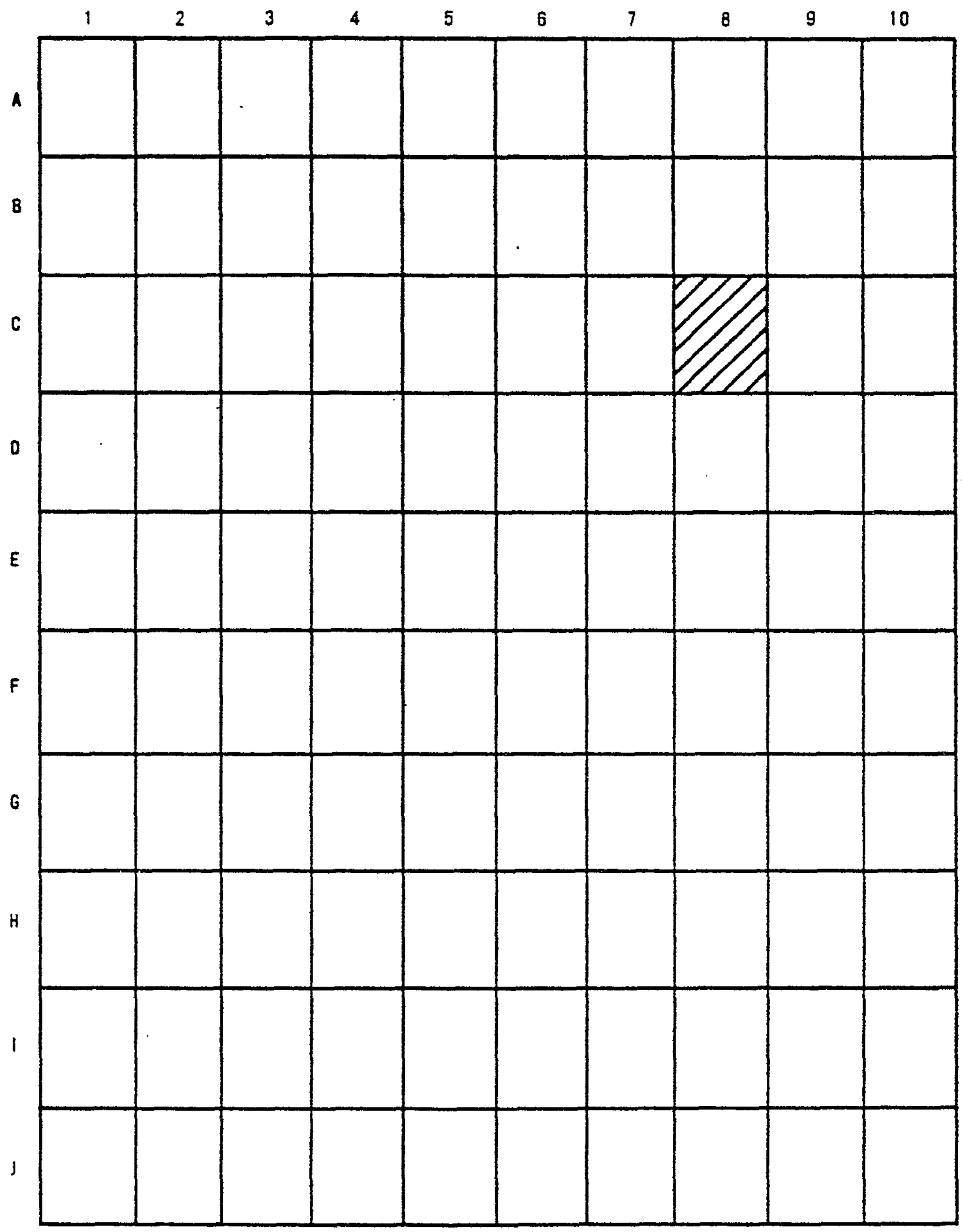

FIGURE 10
ELEMENT LOCATION

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effort. In the early probing for information it soon became apparent that no single agency or office would be sufficient. The early scope of the effort included investigations in each county courthouse for records of assessment and mapping of mined lands as well as visits to county and regional planning groups for maps indicating densities of population and existing and future land use. It soon became apparent that among the counties involved, wide diversity exists regarding the extent and quality of information available. This is especially true of the availability of maps of mined land and assessment information but exists in the planning agencies as well depending upon the degree to which planning has occurred in each county.

An initial interest was to locate areas of previous subsidence. Newspaper records and Subsidence Insurance Claims Reports form a large history of subsidence in the Northern Field. An intensive effort was made in the DER, Bureau of Land Protection, Division of Mine Subsidence Insurance Office in Wilkes Barre to identify each insurance holder that had a claim resulting from subsidence damage. Newspaper records were also collected and subsidence indicated by these two data sources were plotted. Claims records were made and filed for reference to evaluate the accuracy of the model.

Since mine water pools and their fluctuations have been identified as a critical parameter affecting stability, information was collected in the DER Subsidence Office in the form of a bore-hole monitoring map for the northern field with monthly update listings of the mine pool elevations and their fluctuations.

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Since coal extraction within each ~~mine~~ (red) is the single most important factor governing the likelihood of subsidence, a concentrated effort was made to identify the most comprehensive files of mine maps that could be used. Some considerations included the overall scope of territory involved which precluded any one mining company from representing more than a small percentage of the area under study. Also since all deep mining had ceased in the Northern Field and most mining is surface mining in all the fields, many of the original custodians of the maps (i.e., active mining companies) have gone out of existence. In some cases this has resulted in destruction of the maps either intentionally or from poor storage conditions.

The DER Office of Resources Management Anthracite Region Suboffice, in Pottsville has a large collecti of mine maps and proved to be a useful source. A practical consideration in the use of the mine maps for a given area was the accurate positioning of them with respect to the surface. Since most maps are 1"=100' scale and are very large, the arrangement of the mine map sheets relative to each other and the surface for each coal bed mined is a time consuming task requiring a great deal of space and a knowledge of the area and the collieries. These considerations and the fact that the DER collection of maps is not necessarily complete for each colliery led the data collection team to consider the folio method of mine map documentation that is being conducted at the USBM offices in Wilkes Barre and Schuylkill Haven. The folio method was undertaken to study subsidence of the levee system of the Wyoming Valley by the

USBM, the USGS, and the Army Corps of Engineers as reported in the Northeast Flood Study, Susquehanna River, Pennsylvania.[15] It has been extended to other areas since then. After obtaining permission from the officials at USBM to extract information from the folios, a system was established to complete coal extraction data for all the territory represented by the folios. A description of the folios and data collection system follows.

2.3.1.2 Mine Map Folios. Approximately two-thirds of the coal lands in the Northern Field and a part of the coal lands in the Western Middle and Southern Fields have been divided into sections called Panels and subdivided into rectangular areas by the United States Bureau of Mines in the Wilkes Barre and Schuylkill Haven offices. Each subdivision is usually 4200' x 3000' and is represented by a series of maps comprising a Folio. The panels lie in a Northwest-Southeast direction in the Northern Field and nearly a North-South direction in the lower fields. Each Folio group within each Panel forms either the entire area or part of the coal measures across the field depending upon whether or not that Panel is complete. All Panels and Folios are arranged by a number and letter system on a set of "Key" Maps made up from Quadrangle maps at a scale of 1:24,000.

A Folio is so named because each one contains essential information regarding that area in a stratigraphic sequence of maps from the surface to the lowest mined coal bed arranged in correct geographic orientation to each other. Each mined seam is usually represented by one map but in some cases more than one seam level is shown on a map. The maps of the coal beds are blueprints of original mine maps obtained from the various collieries and arranged in the folios without regard to colliery boundaries. These maps contain the most authentic information obtainable concerning underground mine workings. The surface map indicates geographic features of the area including surface elevations. One or more cross sections of the area are usually included and indicate general information such as beds mined and unmined, surface contour, overburden depth, coal bed thickness, rock thickness between beds, dip of beds and beds backfilled. A structure contour map of the bedrock surface is usually included in the Northern Field. Most folios are at a scale of 1"=100' but some in the Southern region are 1"=200' and are made from microfilm prints. The mine map prints are detailed graphic descriptions of how the bed was mined as viewed from above. The coal beds are commonly inclined and therefore the view is foreshortened. The dip angle of the beds range from 0° to 90°. Because of the dip the view depicted can best be described as the projection of a slanted line on a horizontal plane (Figure 11). Each folio is further subdivided into 6" squares (or 600' x 600') called blocks. Since most folios are 4200' x 3000', the blocks form a grid as shown.

	1	2	3	4	5	6	7
A							
B							
C							
D							
E							

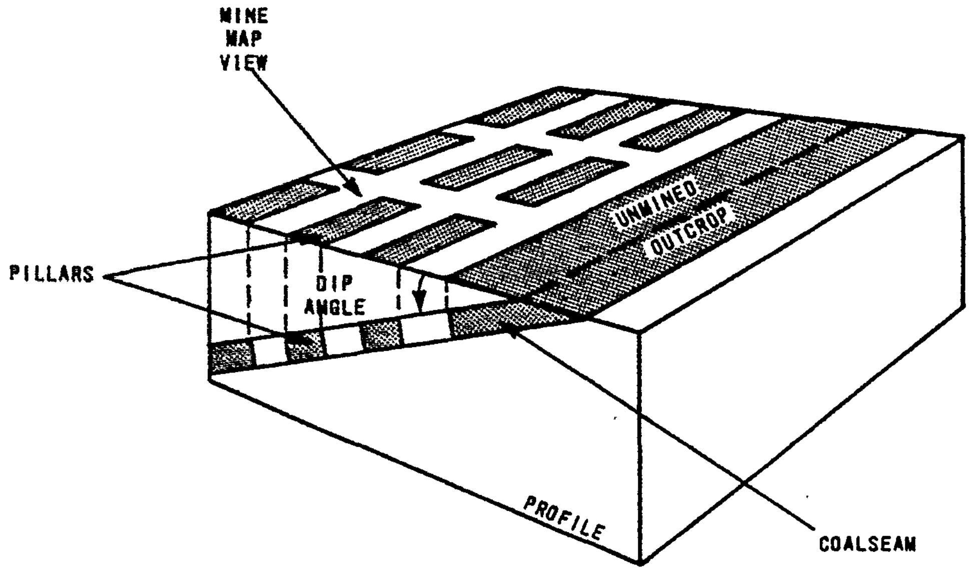

FIGURE 11 BLOCK DIAGRAM ILLUSTRATING MINE MAP PROJECTION

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An initial task in the extraction of data from these folios was the orientation of the folio grid system to the quadrangle element system. Neither the size nor the north-south orientation were the same. The orientation of the folio grid lines were perpendicular and parallel to the general strike of the coal measures while the elements on the quadrangle maps run north-south and east-west. To facilitate transfer of data from the folio to each element, acetate overlays of the grid system for the quadrangles and the overlay of the folio "Key" block system were made at a scale of 1:24,000. The element grid system could then be positioned over the folio key map and folio blocks chosen to represent each overlying element. Data was collected for each element and not from each block. The elements are considerably larger than a block (representing ≃ 40 acres) and oriented at an angle to the block boundaries

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as described above. Approximately four (rad) blocks equal the same area as an element but because of the skewness of their orientation, information covering 6-9 blocks per folio was generally used in determination of the element parameter characteristics. In all cases the worst 10% of the mine map information covered by an element was entered on the data collection sheets.

2.3.1.3 Data Collection Procedure - Work Sheet. To facilitate collection of data from the folios and mine maps, a field mining work sheet was designed that would contain all necessary information from the maps for each element from the surface to the bottom coal bed. Figure 12 is an example of a work sheet. The uppermost portion of the sheet designates the identifiers for each element. The Folio, Location, and Colliery is the identification given by the USBM and their mine maps. The blocks in the upper right are the location identifiers for the Quadrangle, Section, Element, Subelement, Sheet, and Type according to the HRB-Singer system of identification. The Engineer and Date gives the data collector's name and the day he worked on that location.

The actual information from the maps begins in the upper left of the sheet with the surface elevation. The surface elevation was obtained from several different sources. Borehole notations, top of shaft elevations, surface map contours, or quadrangle map contours are common sources. Bed rock surface was given in some folios in the Northern Field on a bed rock surface contour map. This was included because of the large differences between the surface and top-of-rock elevations as a result of the alluvium

SURFACE ELEVATION ________ FOLIO ________ ENGINEER ________ LOCATION/SHEET [| | | | | | | B]

QUAD SEC ELEM SUBELEC SHEET TYPE

LOCATION ________ DATE ________

COLLIERY ________ SAME AS: [| | | | | |]

BED ROCK SURFACE [| | |]

ELEVATION (FT)

(D.1.) -ENTRY TYPE
A-DRIFT
B-TUNNEL
C-SLOPE/PLANE
D-SHAFT

(E.1.)-MINING METHOD
A-ROOM & PILLAR
B-CHUTE/PITCH
C-LONG WALL
D-STRIP

(E.2.)-% EXTRACTION
A- > 80
B-70-80
C-50-70
D- < 50

(E.3.)-MATERIAL
A-MINE REFUSE
B-SAND
C-STONE
D-CULM
E-OTHER ________

(E.5.)-METHOD
A-HANDPACKING
B-MECHANICAL STOWING
C-PNEUMATIC STOWING
D-HYDRAULIC STOWING
E-CAVING
F-OTHER

(D.2.) PILLAR TYPE
A-BARRIER
B-SUPPORT

(D.3.)-PILLAR CONDITION
A-THRUST
B-CREEP
C-CRUSH
D-GOOD

(D.5.) AVER. PILLAR AREA (SQ. FT.)
A- > 2000
B-1500-2000
C-1000-1500
D-500-1000
E- < 500

(D.4.) % EXTRACTION
A- > 90
B-70-90
C-50-70
D- < 50

(D.6.) AVER. MINIMUM DIMENSION(FT.)
A- > 30
B-20-30
C-10-20
D- < 10

ENTRY: [ ] (D.1.) [| | |] UPPER ELEV. (FT) [| | |] LOWER ELEV. (FT) [|] WIDTH (FT) [|] HEIGHT (FT)

SEAM	CODE	ELEV.	THICK.	DEPTH	DIP	W	METHOD (E.1.)	% EXT. (E.2.)	BACK. MAT.(E.3.)	BACK. METH. (E.5.)	P.-TYPE (D.2.)	P.-COND.(D.3.)	P.-% EXT.(D.4.)	P.-AREA (D.5.)	P.-MIN. DIM. (D.6.)	YEAR		NOTES

FIGURE 12 MINE MAP FOLIO DATA COLLECTION SHEET

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of the Wyoming Valley (The Buried Valley).

Below the bed rock surface block is a choice of mine entry types (D.1.). Each entrance is shown on the mine maps as one of the four types - drift, tunnel, slope/plane, or shaft. The upper and lower elevations, width, and height were obtained by measuring the opening on the maps. Vertical shafts are most common and their length as well as width was given. The height of a vertical shaft was found by subtracting the elevation of the lowest coal bed where the shaft appeared from the surface elevation.

With the exception of miscellaneous notes, all other data was taken for each coal bed (or seam) that appeared as mined in that location. Since most seams were known by many names depending upon the location, the colliery, and the mining company personnel who were mining them, a seam code was assigned from the standard geologic section. (See Tables 4, 5, 6, and 7 in Section 1.4.2.)

The seam elevation is taken from the floor of the mine and as near to the center of the element as it could be found on the maps. The thickness was found the same way and was recorded as the vein thickness. The depth was calculated by subtracting the bed elevation from the surface elevation. The dip is the degree and direction the bed is inclined from the horizontal as measured in a vertical plane oriented normal to the strike. It was recorded as an angle and compass direction as indicated on the mine maps. If there were numerous dips in the area, an average dip was assigned and circled, e.g., 5 SE. When there were no dip notations present, they were calculated by finding three elevations to get a general overall dip for the element.

The "W" column represents the width or the representative span of unsupported distance in the area under study. This could be the width of the chambers, the width of a gangway, the width between reserve pillars in a robbed area, or one of several combinations of situations depending upon the type and extent of extraction. Where odd configurations appeared, the figure recorded was measured across the cavity at the widest point. Figure 13 illustrates the technique. If such a width was equal to or greater than 600 feet, 600 or 600+ was recorded since that was the length of one side of a block on the folios.

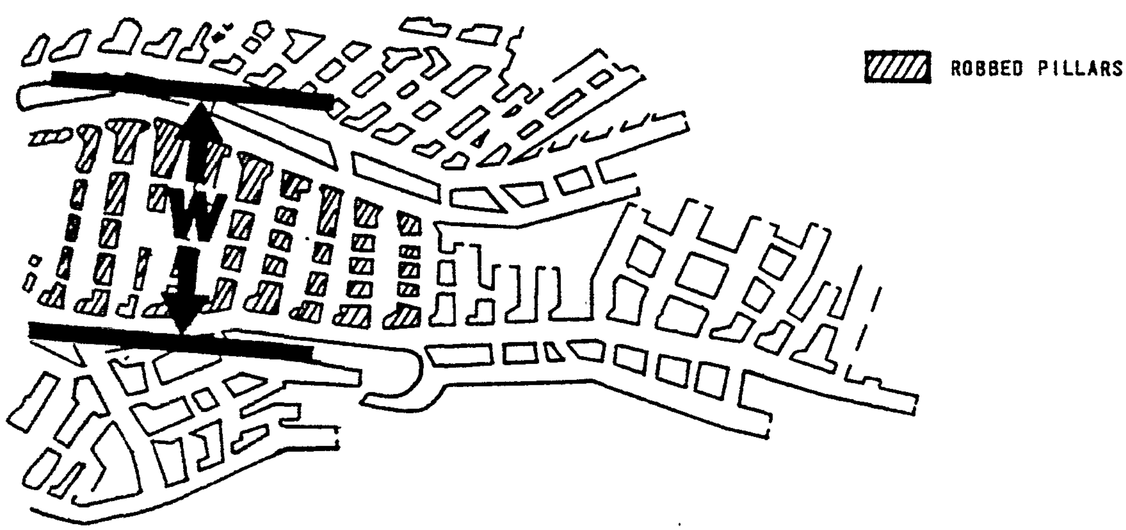

FIGURE 13 MINE MAP SHOWING METHOD OF MEASURING WIDTH (SPAN) OF UNSUPPORTED OPEN DISTANCE. HATCHED LINES INDICATE ROBBED PILLARS.

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The next group of data taken for each seam (E.1. - D.6.) was arranged as multiple choice entries to speed up the data collection process. E.1. is the Mining Method and could be room and pillar, chute/pitch, long wall, or stripping. The choice was made by checking the chamber and pillar outlines. Most often the room and pillar method was indicated. Chute and pitch was not indicated even in highly dipping beds and is a modified version of room and pillar extraction using gravity to transport the coal down the chambers to the gangways. Long wall mining is not common in the Anthracite Region but some was indicated in the Scranton area. It is so labelled on the mine maps. The surface maps and outcrop areas of the mine maps indicate areas of stripping. It should be noted however, that much of the stripping in the present and recent past is not noted on the folios. Since deep mining and stripping was usually done in the same area, stripping information is given in the notes. Other sources of information are necessary to bring stripping locations and depths up to date. If an area was partly deep mined and partly stripped, the entry was recorded as A/D.

E.2. denotes Percent of Extraction of available coal. Extraction information was given in percentage ranges of the ratio of mine map surface area of the chambers to the total area. An engineers' scale was laid across the chambers measuring the open area widths compared to pillar widths and other unmined areas. No allowance was made for the foreshortening of the maps due to the dip angles. The thickness of the removed coal was taken from two thicknesses recorded on the maps - vein thickness and coal thickness. The vein thickness was usually greater and that was the number used rounded off to the nearest foot. When no thickness was given, a thickness value was taken from adjacent areas. Information regarding unmined areas and large supports such as barrier pillars was given in the notes. An area with greater than 90% extraction was considered to be robbed. Extraction of 70% - 90% occurred when chambers were much larger than pillars. 50% to 70% extraction was recorded when the chambers are the same size or somewhat larger than the pillars. Less than 50% extraction occurred when the pillars are larger than the chambers. Worst case conditions were used measuring the largest open widths in robbed areas. When a measurement extended out of the block, it was marked 600 or 600+. Care was taken to instruct each data collector to follow the same procedure for determining his choice of the percentage removed. Note that the percentage ranges from which to choose are sufficiently broad that minor errors in measurement would not affect the choice.

E.3. designates the type of Backfill Material that was deposited in some parts of some beds. Symbols made by the mine maps draftsmen denoted the material type and the Method of Backfilling (E.5.) There was seldom any indication of whether or not the cavities were completely filled. Other data such as boundaries of flushing projects have been used to determine areas that would be significantly affected by backfilling.

D.2. denotes Pillar Type, either a support pillar or a barrier pillar. Each location being investigated was sufficiently large that where a barrier pillar between two collieries was present, support pillars were also present. Where this

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occurred the information for D.2. as well as D.4., D.5., and D.6. was taken from the support pillars and special note of the existence and dimensions of the barrier pillar was made in the notes. Support pillars were taken to be division pillars, reserve pillars, or the smaller pillars within the rooms. D.3. - Pillar Condition is not given on mine maps and in almost all cases is not known today.

D.4. - Percent Extraction is the percent of a pillar removed during second and third mining. The maps rarely showed existence of pillars partially removed. Therefore this block was usually left blank as was D.3. The maps were updated for second and third mining activities but when as much coal as possible had been removed without roof collapse, the pillars were often designated as removed even though many of them almost certainly remain in total or as split pillars.

D.5. Average Pillar Area and D.6. Average Minimum Dimension were taken for a representative pillar within the location being studied. Judgment on the part of the data collector was necessary to choose that representative pillar and then to scale it for the large and small dimensions. The small dimension for that pillar became the dimension used to select the correct range of the Average Minimum Dimension (D.6.) By multiplying the large and small dimension of the pillar the approximate area (D.5.) was established to select the appropriate area range. Here again no allowance is made for the foreshortening of dimensions on the maps because of the dip of the beds. This is especially critical in the Western Middle and other southern fields where the coal is steeply inclined.

The year of mining was taken from the mine maps wherever it could be found. These dates were frequently given in only a few locations across the maps.

The notes contain not only information about stripped areas and robbed areas, but any additional information that might affect the stability of the mine roof. Examples of such notes are division pillar dimensions if present, proximity to unmined areas, as well as notations of squeeze areas, faulting areas, or pillar splitting.

All of the types of data discussed so far are repeated for each element and for each bed mined in a given element. It should be kept in mind that for each bit of information extracted, a finite dimension, notation, or condition was selected to represent each element of approximately 40 acres. Approximately 10% of each elemental area was chosen that appeared to have the most severe conditions that would contribute to subsidence. The 40 acre resolution used for this study was necessary to be able to complete such a large data collection effort within the constraints of the contract. To assess any particular area for a particular use or planned use would require an intensive investigation similar to that carried out by the state for school building locations.[2] In all but the Northern field, the elevations were translated to the center of the element as described in Section 2.3.1.4.

2.3.1.4 Elevation Shift - Western Middle, Eastern Middle, and Southern Fields. Because of the variations of the dip of the strata in these fields it is likely that the angle recorded as the dip at the center of each 40 acre element is not exact. The variations

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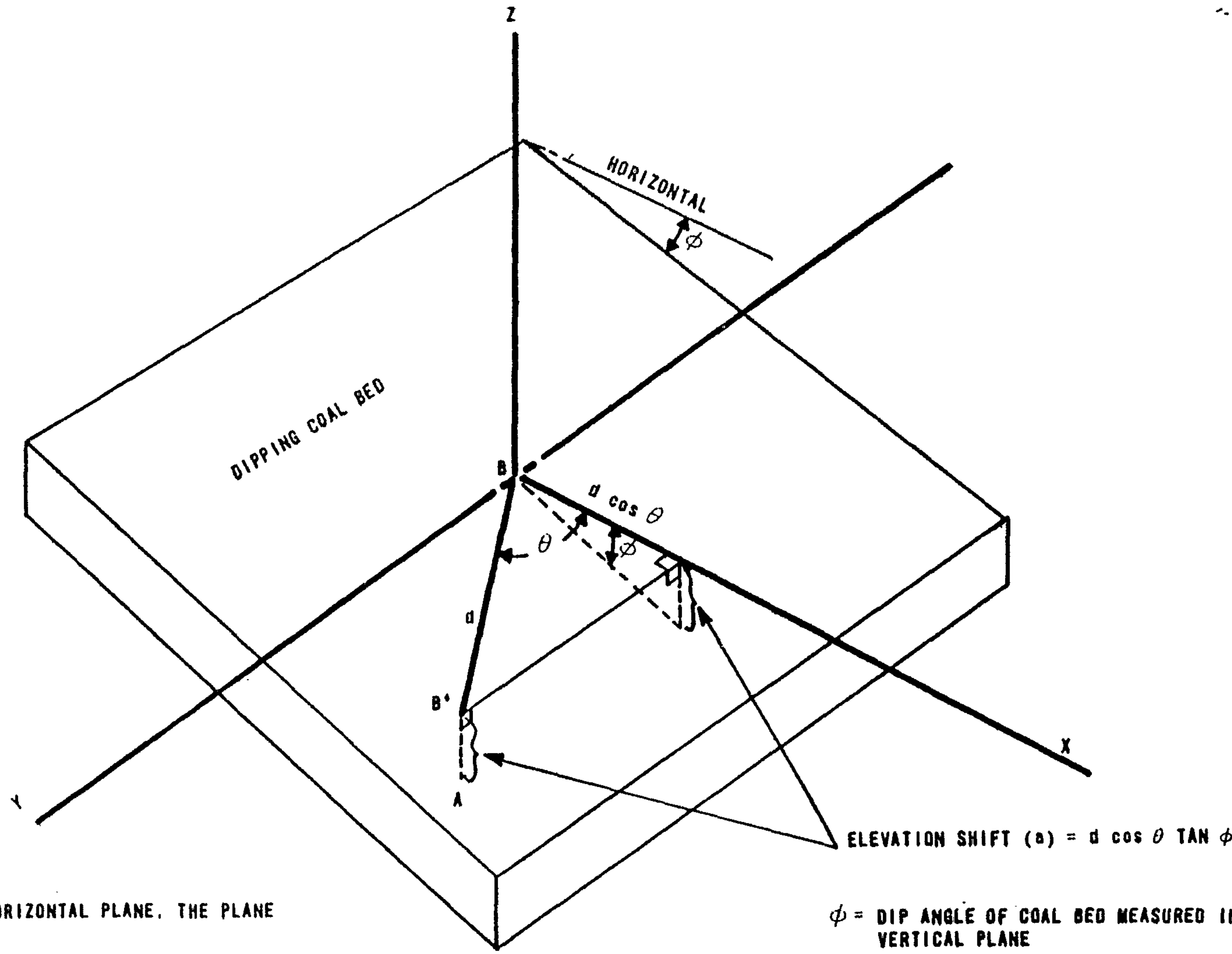
in the dips of the coal beds and the fact that the bed elevations are usually not given on the mine maps at the element center necessitated a trigonometric conversion of the elevation at the point recorded to what it should be at the element center. This conversion is called the Elevation Shift and was accomplished for each bed in each element as follows: The distance d (Figure 14) from the center to the known elevation is measured on the map. The dip angle direction is drawn in and the angle θ is measured to within 5°. The Cos θ multiplied by the distance d is the distance from the center to a point B' on the plane of the center directly above or below the known elevation. The Tan ϕ multiplied by the distance d Cos θ, gives the elevation shift (a) to the center point; $a = d \cos \theta \tan \phi$. To find the coal seam elevation at the element center the elevation shift was either added or subtracted depending on the value of the known elevation. To simplify this process Table 8 was made to find these elevation shifts. This table is a tabulation of the ELEVATION SHIFT PER FOOT of distance (d). The table was calculated for dip (ϕ) from 0° to 90° and shift angles (θ) of 0° to 90° in five degree steps (0°, 5°, 10°, . . . 90°). The dip angle (ϕ) is listed along the horizontal axis and the shift angle (θ) is listed along the vertical, with the elevation shift per foot given in the boxes between the axes. When the elevation of the center is found and recorded the data for one bed is complete and work can begin on the next bed. Before moving on to the next element the surface elevation for the center must be obtained. This elevation is obtained from the spot elevation or contour line nearest the element center taken from a surface elevation on one of the seam maps, or



X,Y AXES FORM A HORIZONTAL PLANE, THE PLANE OF THE MAP.

X,Z AXES FORM A VERTICAL PLANE IN WHICH THE DIP IS MEASURED.

A = KNOWN ELEVATION OF COAL BED

B = UNKNOWN ELEVATION OF ELEMENT CENTER ON COAL BED

B' = ELEVATION UNKNOWN

d = MEASURED MAP DISTANCE

ϕ = DIP ANGLE OF COAL BED MEASURED IN VERTICAL PLANE

ϑ = SEPARATION ANGLE MEASURED IN HORIZONTAL PALNE

FIGURE 14 . 3-DIMENSIONAL VIEW OF ELEVATION SHIFT

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TABLE 8 ELEVATION SHIFT PER FOOT ($\times 10^{-2}$)

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THESE NUMBERS MULTIPLIED BY THE DISTANCE (SEE FIGURE 14) GIVE THE ELEVATION SHIFT IN FEET

DIP ANGLE ψ →

ANGLE θ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
0					9	10	12	14	16	18	19	21	23	25	27	29	31	32	34	36	38	40	42	45	47	49	51	53	55	58	60	62	65	67	70	73	75	78	80	84	87	90	93	96	100
5					9	10	12	14	16	18	19	21	23	25	27	29	30	32	34	36	38	40	42	44	46	49	51	53	55	57	60	62	65	67	70	72	75	78	80	84	87	90	93	96	100
10					9	10	12	14	16	17	19	21	23	25	26	28	30	32	34	36	38	40	42	44	46	48	50	52	55	57	59	61	64	66	69	72	74	77	80	83	86	89	92	95	98
15					8	10	12	14	15	17	19	20	22	24	26	28	29	31	33	35	37	39	41	43	45	47	49	51	54	56	58	60	63	65	68	70	73	75	78	81	84	87	90	93	97
20					8	10	11	13	15	17	18	20	22	23	25	27	29	30	32	34	36	38	40	42	44	46	48	50	52	54	56	59	61	63	66	68	71	73	76	79	82	85	88	91	94
25					8	9	11	13	14	16	18	19	21	23	24	26	28	29	31	33	35	37	38	40	42	44	46	48	50	52	54	57	59	61	63	66	68	71	73	76	79	82	84	87	91
30					8	9	11	12	14	15	17	18	20	22	23	25	26	28	30	32	33	35	36	39	40	42	44	46	48	50	52	54	56	58	61	63	65	68	70	73	75	78	81	84	87
35					7	9	10	11	13	14	16	17	19	20	22	23	25	32	28	30	31	33	35	36	38	40	42	44	45	47	49	51	53	55	57	60	62	64	66	69	71	74	76	79	82
40					7	8	9	11	12	13	15	16	18	19	21	22	23	25	26	28	29	31	32	34	36	37	39	41	42	44	46	48	50	52	54	56	58	60	62	64	66	69	71	74	77
45					6	7	9	10	11	12	14	15	16	18	19	20	22	23	24	26	27	29	30	31	33	34	36	38	39	41	42	44	46	48	49	51	53	55	57	59	61	64	66	68	71
50					6	7	8	9	10	11	12	14	15	16	17	18	20	21	22	23	25	26	27	29	30	31	33	34	36	37	39	40	42	43	45	47	48	50	52	54	56	58	60	62	64
55					5	6	7	8	9	10	11	12	13	14	15	16	17	19	20	21	22	23	24	25	27	30	29	30	32	33	34	36	37	39	40	42	43	45	46	48	50	52	53	55	57
60					4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	28	29	30	31	32	34	35	36	38	39	40	42	43	45	47	48	50
65					4	4	5	6	7	7	8	9	10	10	11	12	13	14	15	15	16	17	18	19	20	21	21	22	23	24	25	26	27	28	30	31	32	33	34	35	36	38	39	41	42
70					3	4	4	5	5	6	7	7	8	8	9	10	10	11	12	12	13	14	14	15	16	17	17	18	19	20	21	21	22	23	24	25	26	27	28	29	30	31	32	33	34
75					2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	13	13	14	14	15	16	16	17	17	18	20	19	20	21	22	22	23	24	25	26
80					2	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17
85					1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9
90					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ANGLE θ	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
0	103	107	111	115	119	123	128	133	138	143	148	154	160	166	173	180	188	196	205	214	225	236	248	206	275	290	308	327	349	373	401	433	470	514	567	631	712	814	951	1143	1430	1908	2864	5729	00
5	103	107	111	115	119	123	128	132	137	142	148	153	159	166	173	180	187	196	204	214	224	235	247	260	274	289	307	326	247	372	400	431	469	512	565	629	709	811	948	1139	1425	1900	2853	5707	00
10	102	106	109	113	117	122	126	131	135	140	146	152	158	164	171	178	185	193	202	211	221	232	244	257	271	286	303	322	343	368	380	427	463	507	559	622	701	802	937	1126	1408	1879	2820	5642	00
15	100	103	107	111	115	119	124	128	133	138	143	149	155	161	167	174	182	190	198	207	217	228	239	252	265	281	297	316	337	360	387	418	454	497	548	610	687	787	919	1104	1381	1843	2766	5534	00
20	97	101	104	108	112	116	120	125	129	134	139	145	150	156	163	169	177	184	193	202	211	221	232	245	258	273	289	307	328	351	377	407	442	483	533	593	669	765	894	1074	1344	1793	2691	5383	00
25	94	97	101	104	108	112	116	120	124	129	134	140	145	151	157	163	170	178	186	194	204	214	224	236	249	263	279	296	316	338	363	393	426	466	514	572	645	738	862	1036	1296	1729	2595	5192	00
30	90	93	96	100	103	107	111	115	119	124	128	133	139	144	150	156	163	170	178	186	194	204	214	226	238	252	267	283	302	323	347	375	407	446	491	547	616	705	824	990	1238	1652	2480	4961	00
35	85	88	91	94	98	101	105	109	113	117	121	126	131	136	142	148	154	160	168	176	184	193	203	213	225	238	252	268	286	306	329	355	385	421	465	517	583	667	779	936	1171	1563	2346	4693	00
40	79	82	85	88	91	94	98	102	105	109	114	118	123	127	133	138	144	150	157	164	172	180	190	200	210	222	236	251	267	286	307	332	360	394	434	484	545	624	729	876	1095	1462	2194	4389	00
45	73	76	79	81	84	87	91	94	97	101	105	109	113	118	122	128	133	139	150	152	159	166	175	184	194	205	218	231	247	264	284	306	333	364	401	446	503	576	673	808	1011	1349	2025	4051	00
50	67	69	71	74	77	79	82	85	88	92	95	99	103	107	111	116	121	126	132	138	144	151	159	167	177	187	198	210	224	240	258	278	302	331	364	406	457	523	611	735	919	1227	1844	3683	00
55	59	62	64	66	68	71	73	76	79	82	85	88	92	95	99	103	108	113	118	123	129	135	142	149	158	167	177	188	200	214	230	248	270	295	325	362	408	467	546	656	820	1094	1643	3286	00
60	52	54	55	58	60	62	64	66	69	71	74	77	80	83	87	90	94	98	103	107	112	118	124	130	137	145	154	164	174	187	200	217	235	257	283	316	356	407	476	572	715	954	1432	2864	00
65	44	45	47	49	50	52	54	56	58	60	63	65	68	70	73	76	79	83	87	91	95	100	105	110	116	123	130	138	147	158	170	183	199	217	240	267	300	344	402	483	604	806	1210	2421	00
70	35	37	38	39	41	42	44	45	47	49	51	53	55	57	59	62	64	67	70	73	77	80	85	89	94	99	105	112	119	128	137	148	161	176	194	216	243	279	325	390	489	653	979	1959	00
75	27	28	29	30	31	32	33	34	36	37	38	40	41	43	45	47	49	51	53	55	58	61	64	67	71	75	80	85	90	97	104	112	122	133	147	163	184	210	246	296	370	494	741	1483	00
80	18	19	19	20	21	21	22	23	24	25	26	27	28	29	30	31	33	34	36	37	39	41	43	45	48	50	53	57	61	65	70	75	82	89	98	110	124	141	165	198	248	331	497	995	00
85	9	9	10	10	10	11	11	12	12	12	13	13	14	14	15	16	16	17	18	19	19	21	22	23	24	25	27	28	30	33	35	38	41	45	49	55	62	71	83	100	125	166	250	499	00
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00

from the topographic map of the area. The data collection procedure is carried out for all portions of the mine map folio which contain centers of elements.

2.3.1.5 Areas not Covered by Folios. For those areas in each of the four fields where folios do not exist, alternate data collection methods had to be initiated. A major part of these areas with the exception of the Eastern Middle Field were represented in the USBM offices with maps of either the 1"=400' or 1"=100' scale. The areas could be identified as either mined or unmined according to recent U.S.G.S. geological maps or from mining depicted on 1":800' maps of the Pennsylvania Second Geological Survey of the 1890's.

The data collection procedure for those areas where maps were available was the same as that for the folios once the maps were arranged in the stratigraphic sequence and identified as to exact colliery location. Each set of maps was for a colliery, so the elements were completed one at a time and colliery-by-colliery. This procedure was sufficient to complete the entire Northern Field except for the Stackhouse Colliery at Shickshinny. All extraction data for the Northern Field was collected by these two methods at the USBM Office in Wilkes Barre.

For those collieries in the Western Middle and Southern Fields near the areas represented in the folios, the mine map copies are being cut and fitted as each folio is completed. Since the remnants of these copies would have been impossible to arrange accurately, those collieries were investigated from mine maps that could be located

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in the DER Resources Management Office in Pottsville. All extraction data collected for the Western Middle and Southern Fields were done in the Schuylkill Haven Office of the USBM and DER Office in Pottsville.

The areas where extraction data could not be collected were treated differently and to varying degrees of detail. Data for the entire Eastern Middle Field were difficult to obtain since neither the Wilkes Barre nor Schuylkill Haven Offices of the USBM have undertaken to retrieve the sets of colliery maps for folio assembly. Some maps are on file with DER but there is no way of knowing if each colliery represented is complete for all beds mined in any specific area without extensive research for each colliery at each custodian location for the colliery maps. An interview with personnel involved with present mining in large areas of the Eastern Middle Field confirmed what had been indicated in the state and federal mining offices - i.e. very few if any coal bearing areas exist where extensive deep mining has not been done. Occurrences of subsidence have been reported in that field but are minimal compared with the Northern Field. This has been attributed to mining practices agreed upon by mine operators in parts of that region long ago whereby 50% of coal was to be the maximum amount removed from any bed in any colliery. A system of drainage tunnels to watersheds in the region keeping many of the mines dry has also been offered as a contributing factor to the stability of the pillars and to the surface. Complete aerial photography flown in July 1974 at a scale of 1:48,000 was available and used to determine all strip mined areas in the Eastern

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Middle Field. On the basis of the above information an element by element determination was made on a mined, stripped, and unknown basis. See Section 3.3.2.

The Southern Field and Western Middle Fields were completed on an element-by-element basis by one of two procedures. Extraction data was collected from folios and other mine maps on file at the USBM Schuylkill Haven Office and mining information was gathered from geological survey maps and checked against mining shown on the maps of the Second Pennsylvania Geological Survey. Where coal extraction data was not collected there is insufficient information to exercise the subsidence potential model. Almost all of the Nesquehoning and Tamaqua quadrangles in the Southern Field and the Ashland and Shenandoah in the Western Middle Field were completed with extraction data. Figure 15 of the Southern Field and Figure 16 of the Western Middle Field show the extent of each type of data collection procedure.

2.3.2 Data Processing. The final step in the data collecting processes took the form of a subsidence data summary sheet. A representative completed data sheet for the elemental area SCR7B9 is shown in Figure 17. A similar summary sheet was compiled for each element in the Northern Anthracite Field and for those elements in the Southern and Western Middle fields where coal extraction data was collected. A key to the subsidence data summary sheet is found in Table 9. After the subsidence data summary sheets were completed the contained data were keypunched onto computer cards and fed into the computer for processing.

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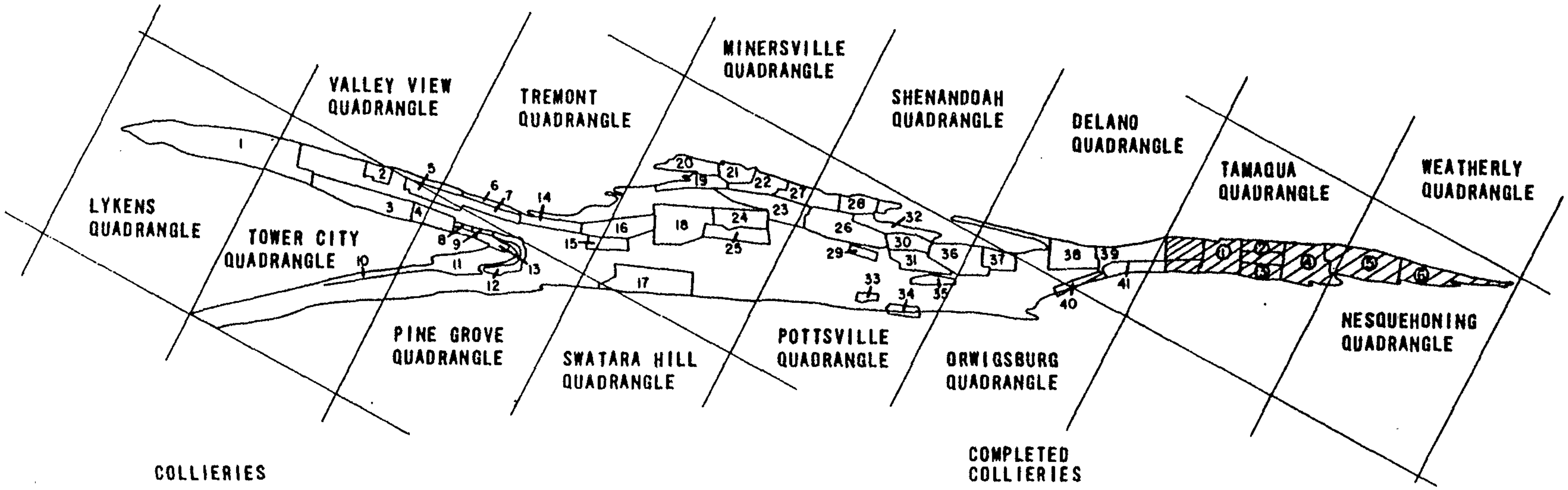

COLLIERIES

1. LYKENS-WILLIAMSTOWN
2. MARKSON
3. BROOKSIDE
4. TOWER CITY
5. GOOD SPRING NO. 1
6. PENAG
7. GOOD SPRING NO. 3
8. JOLIETT
9. WESTWOOD
10. KALMIA
11. LINCOLN
12. RAUSCH CREEK
13. NEW LINCOLN
14. COLKET
15. INDIAN HEAD
16. MIDDLE CREEK
17. BLACK WOOD
18. OTTO
19. BUCK RUN
20. GLENOWER
21. RICHARDSON
22. THOMASTON
23. OAK HILL
24. LYTLE
25. PHOENIX PARK
26. WADESVILLE
27. PINE KNOT
28. REPPLIER
29. POTTSVILLE
30. ST. CLAIR-PINE FOREST
31. EAGLE HILL
32. ST. CLAIR
33. SALEM HILL
34. RANDOLPH
35. PALMER VEIN
36. SILVER CREEK
37. KASKA
38. MARY D
39. TAMAQUA LANDS
40. BELL
41. NEWKIRK

COMPLETED COLLIERIES

1. TAMAQUA
2. GREEN WOOD
3. RAHN
4. COALDALE
5. LANSFORD
6. NESQUEHONING

AREA COMPLETED

- COMPUTER MAPS FROM FOLIO & MINE MAP DATA GEOLOGICAL SURVEY MAPS
- SECOND PENNSYLVANIA GEOLOGICAL SURVEY U.S. GEOLOGICAL SURVEY - C.I.GQ MAP SERIES

FIG. 15 EXTENT AND TYPE OF DATA COLLECTED - SOUTHERN ANTHRACITE FIELD

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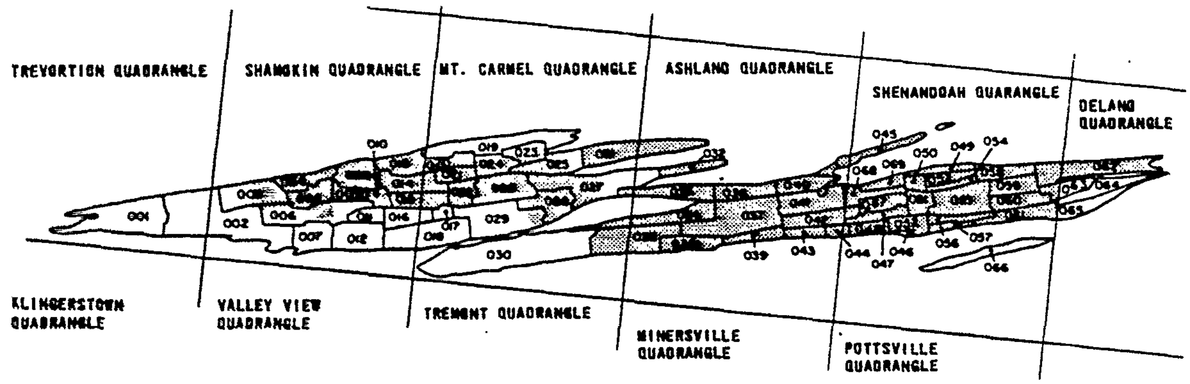

COLLIERY KEY

MINE	MINE INDEX NUMBER	LOCATION OF MINE[1]
NORTH FRANKLIN	W001	SHAMOKIN
BEAR VALLEY	W002	DO
ASHLD COAL CO.	W002-A	DO
GLEN BURN[2]	W003	DO
CAMERON	W004	DO
NEILSON	W005	DO
STIRLING HENRY CLAY	W006	DO
BURNSIDE	W007	DO
LUKE FIDLER	W008	DO
ROYAL OAK	W009	DO
BUCK RIDGE NO. 2	W010	DO
BUCK RIDGE NO. 1 GREENBACK	W011	DO
BIG MOUNTAIN	W012	DO
HICKORY SWAMP	W013	SHAMOKIN-MOUNT CARMEL
COLBERT	W014	DO
MAYSVILLE 1 AND 2	W015	DO
CORBIN	W016	DO
EXCELSIOR[3]	W017	DO
ENTERPRISE	W018	DO
NATALIE	W019	DO
HICKORY RIDGE	W020	MOUNT CARMEL
SCOTT RIDGE	W021	DO
SCOTT[4]	W022	DO
RICHARDS WATER LEVEL	W023	DO
GREENOUGH	W024	DO
RICHARDS SHAFT	W025	DO
PENNSYLVANIA	W026	DO
SAYRE	W027	MOUNT CARMEL-ASHLAND
MORRIS RIDGE	W027-A	DO
SIOUX 1 AND 3	W027-B	MOUNT CARMEL
RELIANCE	W028	DO
ALASKA	W029	DO
LOCUST GAP	W030	DO
MIDVALLEY 1 & 2 BASINS	W031	MOUNT CARMEL-ASHLAND
MIDVALLEY NO. 2	W032	ASHLAND
CENTRALIA	W033	DO
LOGAN	W033-A	MOUNT CARMEL-ASHLAND
GERMANTOWN	W034	DO
POTTS	W035	DO

SEE FOOTNOTES AT END OF TABLE.

MINE	MINE INDEX NUMBER	LOCATION OF MINE[1]
CONTINENTAL	W036	ASHLAND
BAST	W037	DO
BACROFT AND TUNNEL	W038	DO
PRESTON NO. 3	W039	DO
RAVEN RUN OR MAMMOTH	W040	DO
HAMMOND	W041	DO
DO	W041-A	DO
PACKER NO. 5	W042	ASHLAND-SHENANDOAH
GIRARD	W043	ASHLAND
WEST BEAR RIDGE	W044	ASHLAND-SHENANDOAH
WESTON	W045	DO
DRAPER[5]	W046	SHENANDOAH
KIMBERLY-DRAPER	W046-A	DO
EAST BEAR RIDGE	W047	DO
LAWRENCE	W048	DO
KEHLEYS RUN	W049	DO
KOHINOR	W050	DO
WEST SHENANDOAH	W051	DO
GILBERTON	W052	DO
INDIAN RIDGE	W053	DO
SHENANDOAH CITY[6]	W054	DO
MAPLE HILL	W055	DO
SAINT NICHOLAS	W056	DO
BOSTON RUN	W057	DO
KNICKERBOCKER	W058	DO
NORTH MAHANOY	W059	DO
MAHANOY CITY	W060	DO
TUNNEL RIDGE	W061	DO
PARK 1 AND 2	W062	SHENANDOAH-DELANO
PRIMROSE	W063	DO
PARK 3 AND 4	W064	DO
VULCAN-BUCK MOUNTAIN	W065	DO
MOREA-NEW BOSTON	W066	SHENANDOAH
WILLIAM PENN	W067	DO
PACKER 2 AND 4	W068	ASHLAND-SHENANDOAH
PACKER NO. 3	W069	SHENANDOAH

[1] NAMES IN THIS COLUMN REFER TO U.S. GEOLOGICAL SURVEY QUAD.

[2] ACTIVE. NOT MICROFILMED.

[3] INCLUDED IN CORBIN (W016).

[4] INCLUDED IN SCOTT RIDGE (W021).

[5] INCLUDED IN GILBERTON (W052).

[6] INCLUDED IN INDIAN RIDGE (W053).

COMPUTER MAPS GENERATED

FIG. 16 EXTENT AND TYPE OF DATA COLLECTED - WESTERN MIDDLE ANTHRACITE FIELD

74-144

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COMMENTS: COLLIERY — HYDE PARK

LOCATION	SAME AS	SURFACE ELEV.	SOIL THKNESS	FLOOD LEVEL	POOL LEVEL	SLOPE	POPULATION	RE VALUE
SCR7B9		885	6	660	604	A	E	

Card columns 51–79: ?

	SEAM CODE	THICKNESS	ELEVATION	% EXTRAC.	LAST MINED	DIP	ROCK COVER	ROCK INTEG.	MIN. PIL. DIM.	MIN. AREA	COLLAPSE	WIDTH	BACKFILL	LITHOLOGY	CONDITION	47	49	51
2	030	4	846	D	14	12SE	29		B	B	?	500	N	A	B			
3	034	5	732	C	18	10SE	109		C	B	?	300	N	A	B			
4	038	6	712	A	08	8SE	14		C	C	?	750	N	A	B			
5	042	11	638	B	12	10SE	63		B	B	?	350	N	B	B			
6	048	4	580	D	14	15SE	54		C	B	?	30	N	B	B			
7	054	3	508	D	15	15SE	69		C	B	?	35	N	C	B			
8	058	3	353	D	08	12SE	152		B	B	?	30	N	B	B			
9	060	4	313	D	06	10SE	36		B	B	N	30	N	B	B			
10	062	5	289	D	06	10SE	19		C	C	?	38	N	A	B			
11																		
12																		
13																		
14																		

7-16 ESB.

FIG. 17 SUBSIDENCE DATA SUMMARY SHEET

74-144

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TABLE 9 SUBSIDENCE DATA SUMMARY SHEET KEY

74-144

CARD	COLUMN	DESCRIPTION - COMMENTS
1	4.	LOCATION - QUAD/SECTION/ELEMENT
	15.	SAME AS - LITTLE USE ON SUMMARY SHEET
	25.	SURFACE ELEVATION - ALL ELEVATIONS IN FEET ABOVE SEA LEVEL.
	29.	SOIL THICKNESS - UNCONSOLIDATED MATERIAL IN FEET WHERE TOP LAYER HAS BEEN STRIPPED. TOP ROCK IS ADDED TO SOIL THICKNESS
	32.	FLOOD LEVEL - HURRICANE AGNES ELEVATION/FEET ABOVE SEALEVEL.
	36.	POOL LEVEL - ELEVATION/FEET ABOVE SEA LEVEL
	40.	SLOPE - AVERAGE FOR ELEMENT; PERCENT SLOPE
	41.	POPULATION - 1970 CENSUS, NUMBER OF PERSONS/ELEMENT
	42.	RE VALUE - $/ACRE (REAL ESTATE VALUE) NOT USED.
	51.	SUBSIDENCE - (Y)ES/(N)O/? WHERE NO DATA IS AVAILABLE: IF YES, PRECEEDS BOX
	52. 53.	YEAR - WHEN FIRST NOTICED AS WELL AS DATE OF SUBSEQUENT OBSERVATIONS
	54. 55.	YEAR (OTHER)
	56.	NO MINING O
	57.	FLUSHED F (COMPLETELY) 58 PARTIALLY FLUSHED G
2	16.	SEAM CODE - FROM TABLES IN SECTION 1.4.2 AND 2.4
	19.	THICKNESS - AVERAGE THICKNESS OF SEAM FOR ELEMENT (FEET)
	21.	ELEVATION - BOTTOM OF SEAM/FEET ABOVE OR BELOW SEA LEVEL
	25.	% EXTRACTION - FROM FOLIOS, MINE MAPS, REPORTS, PERSONNEL COMMUNICATION, ETC.
	26.	LAST MINED - FOLIO DATA; UPDATED WHERE COLLATERAL INFORMATION INDICATING MINING, ROBBING SUBSEQUENT TO MAP/FOLIO DATE IS AVAILABLE. USE LAST TWO DIGITS OF YEAR.
	28.	DIP - ANGLE AND DIRECTION FROM FOLIO OR GEOLOGIC MAP.
	32.	ROCK COVER - (FEET) TOTAL THICKNESS FROM TOP OF SEAM TO BOTTOM OF SEAM ABOVE. FOR UPPERMOST SEAM IT IS THICKNESS FROM TOP OF SEAM TO BOTTOM OF SOIL.
	35.	ROCK INTEGRITY - SEE TEXT
	36.	MINIMUM PILLAR DIMENSION - SEE TEXT
	37.	MINIMUM AREA - SEE TEXT
	38.	COLLAPSE - Y(ES)/N(O)/? WHERE NO DATA IS AVAILABLE
	39.	WIDTH (W) - FEET
	43.	BACKFILL - (Y)ES/(N)O
	44.	LITHOLOGY - SEE TEXT
	45.	CONDITION OF ROCK COVER - SEE TEXT

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Several sources of information were combined in order to produce the summary sheets. A list of these sources includes field mining work sheets, U.S.G.S. Geologic Maps, U.S.G.S. Coal Investigation Studies, U.S.B.M. Barrier Pillar Studies,[3,4] Susquehanna River Flood Studies,[7,15,18] Colliery Records, A.W. Martin's Mine Pool Level Studies,[5] EARTHSAT Studies, and D.E.R. Flushing Project Studies.

The methods and assumptions used in compiling the subsidence data summary sheets are as follows:

LOCATION: The location of each element in the four mining fields was defined by the grid system designed for this project and previously described in Section 2.2.2.

SURFACE ELEVATION: Surface elevation information was taken from the field mining sheet and was entered on the summary sheet as an elevation, measured in feet, above sea level.

SOIL THICKNESS: Soil thickness information was taken from the field mining sheet and was entered on the summary sheet as an average thickness measured in feet. The Hollowell report (1971)[13] was used as a check on the soil thicknesses in the buried glacial valley in the Wyoming Valley. Soil thicknesses in areas other than the buried glacial valley and where no bed-rock surface information was available from mine maps were assumed to be 3 or 4 feet. This assumption was based upon soil thickness information from county soil maps and was used only in the non-glaciated Southern Anthracite Region.

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FLOOD LEVEL: Flood level information was included only in the program for the Northern Anthracite Field where river drainage and hydrogeologic conditions contribute significantly to land subsidence problems. A major source of information was U.S.G.S. Atlas HA 523.

Flood level information was not available for the upper reaches of the Lackawanna River. Flood levels for this region were extrapolated by using the adjacent river gradients and the estimated river level rise during a 100 year flood.

Flood level data was entered on the summary sheet as an elevation measured in feet, above sea level.

POOL LEVEL: Mine water pool level information was entered on the summary sheet in the form of an elevation above sea level, measured in feet. The mine pool information was standardized to the September 1973 reported readings of the Pennsylvania Department of Environmental Resources for the Northern Field.

SLOPE: Four categories of surface slope were established on the basis of percent slope: A - 0 to 4%, B - 5 to 16%, C - 17 to 40%, and D - >40%. The slope of the land surface for each element was calculated from U.S.G.S. topographic maps. Slope was entered on the summary sheet as either A, B, C, or D.

POPULATION: Five classes of population density were established: A(>10,000/element),

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B (1,000-10,000/element), C(100-1,000/element), D(10-100 element), and E(< 10/element). Population density estimates vary according to the land utilization of each element. The 1970 Population Census Estimate was used in calculating the density patterns of each element. These census estimates probably represent a minimum level of density due to the fact that the population which will assume the risks and bear the damages is most likely greater than what the census count reveals. Calculations were made on people per unit, units per acre, and finally people per element. The basic data used to map pupulation density was obtained from the 1972 County and City Data Bank, Population density was entered on the summary sheet as either A, B, C, D, or E.

SUBSIDENCE: Two classes of reported subsidence were established. Previous subsidence in a given element reported in a newspaper, a journal, or recorded in an insurance settlement was given a "Y" classification. A "?" classification was given to all elements where no previous subsidence had been reported by any media.

SEAM CODE:

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Seam code classifications were based on stratigraphic sequence and lateral correlation. Particular emphasis was placed on careful correlation of the coal seams in the Northern Field. These correlations are discussed further in Section 2.4.

The general stratigraphic sequence of coal seams was obtained from geologic maps, coal investigation studies, field mining sheets, and colliery records. A three digit code was established to identify a specific generally accepted stratigraphic coal seam nomenclature to which all other synonomous coal seam names were correlated. This general nomenclature is shown in Tables 4, 5, 6, and 7 in Section 1.4.2. Although, the coal seam codes appear generally similar between fields no correlation was attempted. Each table is to be used strictly for correlation within the specified field. The three digit coal seam code used to designate each mined coal seam was established in the following manner. The stratigraphically highest occurring mined coal seam was given a datum level code. For instance, the #1 vein in the Northern Field was given a 010 code. Every successive stratigraphically lower coal seam was given an even numbered code greater than 010. For example, the #2 vein in the Northern Field was designated 012, the #3 vein was designated 014 and so on. In the case where a coal seam splits, which frequently happens, the stratigraphically higher split was

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designated B; i.e. T10 and B10. Due to the discontinuity of some minor coal seams it was necessary to designate certain seams with odd number codes, 057, 055, etc.

This code was adopted in order to alleviate the confusion caused by the multitude of names given to a single coal seam by the different collieries and to aid in the stratigraphic and lateral correlation of the coal seam. (See Section 2.4).

THICKNESS: Coal seam thickness information was taken from the field mining work sheet and was recorded on the summary sheet numerically in feet. In cases where there was no information on the mining sheet the coal seam thickness was interpolated from adjacent elements or from stratigraphic columns.

ELEVATION: Coal seam elevation data was taken from the field mining sheet and recorded as a numerical value in feet of positive elevation above sea level or negative elevation below sea level. The elevations represent the elevation of the bottom of the coal seam.

The structure contour map of the Lower Red Ash bed (Bergin and Robertson)[7] was used in the Wyoming Valley of the Northern Field as a check on the Lower Red Ash elevations taken from the field mining sheets. Since this is the basal seam in the Northern Field it gave good control on elevation.

% EXTRACTION: Information regarding percent extraction of the coal in the mined coal seam was taken from the field mining sheet and was recorded on the summary sheet according to the following classification: A(>90%), B(70-90%), C(50-69%), and D(<50%).

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LAST MINED: The last year in which mining occurred on a given coal seam was entered in the summary sheet as a two digit number using the last two digits of the year that the coal was last mined (example: 1948, entered 48). In cases where the last year of mining was not known no entry was made on the summary sheet.

DIP: The dip of the coal seam was entered on the summary sheet as an angular measurement in degrees associated with a compass direction (example: 60^{o} south entered 60S). This information was taken from the field mining sheet and where possible checked against dip measurements on geologic maps.

ROCK COVER: Rock cover between consecutively mined coal seams was recorded numerically in feet and was calculated by adding the coal seam thickness to the coal seam elevation and subtracting this sum from the elevation of the next overlying coal seam. The rock cover overlying the stratigraphically highest coal seam in any element was calculated by adding the coal seam thickness to the coal seam elevation and subtracting this from the bedrock surface elevation given on the field mining sheet.

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<u>ROCK INTEGRITY:</u> Rock Integrity is a measure of the strength of a rock of a given lithology and its ability to withstand the strain caused by the differential stress of mining - not used in the algorithm calculations because this factor has not been adequately researched and quantified.

<u>MIN. PIL. DIM.:</u> Average minimum pillar dimension information was taken from the field mining sheet and recorded on the summary sheet according to the following classification: A(>30 feet), B(20-30 feet), C(10-19 feet), and D(<10 feet). If the comments on the field mining sheet stated that the seam was totally robbed a "D" classification was assigned.

<u>MIN. AREA:</u> Average minimum pillar area information was taken from the field mining sheet and recorded on the summary sheet according to the following classification: A(>2000 square feet), B(1500-2000 square feet), C(1000-1999 square feet), D(500-999 square feet), and E(<500 square feet). If the comments on the field mining sheet stated that the seam was totally robbed an "E" classification was entered.

<u>COLLAPSE:</u> A three category classification system was established for entering mine collapse data on the summary sheet. This classification was based on the following criteria; width between pillars, occurrence of backfill, rock condition, and any comments on the mining sheet regarding squeeze, slumping, collapse, or caving. A "Y"

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classification was designated if squeeze, slumping, collapse, or caving was reported. A "N" classification was designated if the width between pillars measurement was less than 50 feet and there was no evidence of faulting in the element or if the seam was completely backfilled. A "? " classification was assigned to any element where no information existed.

WIDTH: The width or representative span of unsupported distance was entered on the summary sheet as a numerical value measured in feet. This information was taken from the field mining sheet.

BACKFILL: A two category classification system was designed to enter the occurrence of backfilling on the summary sheet. If a given coal seam was backfilled a "Y" classification was entered. If a given coal seam was not backfilled a "N" classification was entered. Information regarding the backfilling of the coal seams was taken from the field mining sheets and from flushing projects records in the DER Office in Wilkes Barre. For DER flushing projects a special "F" entry was used in column 57 of card 1 when an element was completely flushed and a "G" used for a partially flushed element.

LITHOLOGY: Lithology of the rock overlying each mined coal seam was entered on the summary sheet according to the following system: A - sandstone, B - shale/slate, C - conglomerate, D - siltstone, E - coal,

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and F - limestone. Information pertaining to the various rock lithologies was taken from U.S.G.S. geologic maps, U.S.G.S. coal investigation studies, and hand-made stratigraphic columns taken from mine records. Classes "E" and "F" were never used.

<u>CONDITION:</u> The physical condition of the rock units containing the coal was entered on the summary sheet according to the following classifications: A - faulted, B - folded, C - jointed or fractured, D - continuous or massive, and E - other. Information pertaining to rock condition was taken from geologic maps, available EARTHSAT data (contract EER-123) compiled for the Northern Field, coal investigation studies, and the field mining sheets. Due to gaps in the rock condition data base it was necessary to make certain fundamental assumptions concerning the condition of the rock units in the coal fields. The gross geologic structure of all the anthracite fields is a sequence of repetitive anticlinal and synclinal folds. Thus, all the rocks are folded and would, therefore, have at least a "B" classification. To avoid assigning the classification to the majority of the rock units it was assumed that the limbs of unfaulted folds were massive and a "D" classification was assigned. In areas where no rock condition data existed a "B" classification was entered on the summary sheet. The classification "E" was never used.

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Subsidence data summary sheets were compiled for every element in the Northern Anthracite Field and for those elements in the Southern and Western Middle Anthracite Fields where mine map information was available. For those areas where no detailed mine map data were available reconnaissance data on a "mined" versus "unmined" basis were used to characterize the elemental area. This data was not entered on a summary sheet, but was used in the compilation of the subsidence potential quadrangle maps.

Completed subsidence data summary sheets were key-punched and taken to the computer facilities for processing. A single computer card was key-punched for each mined coal seam. And, an additional heading card was key-punched to convey the location and general conditions of each element. The information on the cards was fed into the PDP 11/45 computer where it was stored on disks and tapes.

2.4 STRATIGRAPHIC CORRELATION

A major effort was made to correlate coal seams in the Northern Anthracite Field on a colliery by colliery basis. The work of Bergin and Robertson[7] in the Wyoming Valley was extended northeastward to include the Lackawanna Valley. The major sources of information were the mine maps and the Barrier Pillar studies of Ash[3,4] et al.

Correlations were carried from colliery to colliery using the standard seam code adopted in this report. In this manner a seam correlative was always identified by the same seam code number regardless of what name it was known under in any particular colliery. This was done to make the data base a more valuable product. Through re-programming a number of different data analyses and map products could be prepared; for example, a percentage extraction map for the Lower Red Ash (060) seam, or a seam thickness map, or perhaps a sear elevation map (structure contour map).

The seam correlations are displayed in Tables 10 and 11. The collieries are ordered in general sequence proceeding from the south west (Shickshinny) to the northeast (Forest City).

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TABLE 10 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD, WYOMING VALLEY

74-144

SEAM CODE \ COLLIERY NAME	MOCANAQUA	WEST END	WANAMIE	GLENHAN	STERNS	SUSQUEHANNA NO. 8 & NO. 7	LOOMIS	TRUESDALE	AVONDALE-GRAND TUNNEL	INMAN	HUBER	SUGAR NOTCH	NOTTINGHAM	SEAM CODE
010					#1 VEIN									010
012							NO. 2							012
014							NO. 3			NO. 8				014
016							NO. 4			NO. 6				016
018							T18 NO.5 OVERLAP B18 NO. 5			NO. 4				018
020							NO. 6			NO. 3				020
022						TOP GEORGE								022
024				BOTTOM GEORGE		BOTTOM GEORGE	GEORGE	GEORGE			SNAKE ISLAND			024
026					ABBOTT	T26 T. ORCHARD, ORCHARD	ABBOTT			ABBOTT	ABBOTT		ABBOTT	026
028				KIDNEY	KIDNEY	T28 T. MILLS 028 MILLS, KID.	MILLS	MILLS		KIDNEY	KIDNEY	KIDNEY	KIDNEY	028
030				030 HILLMAN B30 BOTTOM HILLMAN	030 MIDDLE HILLMAN B30 BOTTOM HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	030
032											TOP STANTON			032
034						LANCE	BALTIMORE		COOPER	STANTON	STANTON		STANTON	034
036						COOPER B36 COOPER UNDERLAP								036
038						FORGE	FORGE		BENNETT	FIVE FOOT	FIVE FOOT		FIVE FOOT	038
040			TOP BALTIMORE	TOP BALTIMORE	TOP BALTIMORE	040 TOP TWIN B40 TOP TWIN BOTTOM SPLIT				TOP BALTIMORE	TOP BALTIMORE	TOP BALTIMORE	TOP BALTIMORE	040
042		BALTIMORE	BOTTOM BALTIMORE		BOTTOM BALTIMORE	BOTTOM TWIN	TWIN		FORGE	BALTIMORE	BOTTOM BALTIMORE	BOTTOM BALTIMORE	BOTTOM BALTIMORE	042
044														044
046														046
048														048
050	TOP ROSS	T50 ROSS SPLIT 050 TOP ROSS	T50 TOP ROSS			T50 TOP ROSS 050 MID ROSS	TOP ROSS		TOP ROSS		TOP ROSS		TOP ROSS	050
054		ROSS	ROSS	BOTTOM ROSS	BOTTOM ROSS	BOTTOM ROSS	BOTTOM ROSS		BOTTOM ROSS		BOTTOM ROSS	ROSS	BOTTOM ROSS	054
055														055
056	TOP RED ASH		TOP SPLIT TOP RED ASH			CHAUNCEY			CHAUNCEY		TOP RED ASH		TOP RED ASH	056
057														057
058		RED ASH SPLIT	BOTTOM SPLIT TOP RED ASH		BOTTOM SPLIT TOP RED ASH	TOP LEE								058
060	BOTTOM RED ASH	RED ASH	BOTTOM RED ASH	BOTTOM RED ASH	BOTTOM RED ASH	LEE	RED ASH		RED ASH		BOTTOM RED ASH	RED ASH	RED ASH	060
062						BOTTOM LEE								062

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TABLE 10 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD WYOMING VALLEY (CONT'D)

74-144

SEAM CODE \ COLLIERY NAME	NOTTINGHAM-BUTTONWOOD	LANCE	S. WILKES-BARRE	GAYLORD	LOREE	WOODWARD	STANTON	HOLLENBACK	BALTIMORE	KINGSTON	DORRANCE	EAST BOSTON	BLACK DIAMOND	SEAM CODE
010														010
012														012
014														014
016														016
018														018
020														020
022									"C"					022
024					SNAKE ISLAND	SNAKE ISLAND			SNAKE ISLAND		SNAKE ISLAND			024
026	ABBOTT	ABBOTT	ABBOTT	ABBOTT	ABBOTT	ABBOTT	ABBOTT	ABBOTT	ABBOTT		ABBOTT			026
028	KIDNEY	KIDNEY	KIDNEY	BUCKLEY, KIDNEY	LANCE	KIDNEY	KIDNEY	KIDNEY	KIDNEY	BUCKLEY	BUCKLEY			028
030	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN	HILLMAN			030
032							TOP STANTON		TOP STANTON					032
034	STANTON	STANTON	BOTTOM STANTON	BOTTOM FIVE FOOT, STANTON	STANTON	FIVE FOOT	BOTTOM STANTON	BOTTOM STANTON	STANTON	ORCHARD	FIVE FOOT	FOUR FOOT	FOUR FOOT	034
036														036
038	FIVE FOOT	FIVE FOOT	FIVE FOOT	LANCE	FIVE FOOT	LANCE	FIVE FOOT	FIVE FOOT		LANCE	LANCE	LANCE	LANCE	038
040	TOP BALTIMORE	TOP BALTIMORE	TOP BALTIMORE	COOPER	COOPER	COOPER				COOPER	COOPER	COOPER	COOPER	040
042	BOTTOM BALTIMORE	BOTTOM BALTIMORE	BOTTOM BALTIMORE	BENNETT	BENNETT	BENNETT, BALTIMORE	BENNETT, BALTIMORE	BALTIMORE	BALTIMORE	BENNETT	BENNETT BALTIMORE	BENNETT	BENNETT	042
044										CHECKER	CHECKER		TOP ELEVEN FOOT	044
046														046
048									SKIDMORE	ELEVEN FOOT	SKIDMORE	ELEVEN FOOT	ELEVEN FOOT	048
050		TOP ROSS	TOP ROSS		TOP ROSS		TOP ROSS		TOP ROSS					050
054		ROSS		BOTTOM ROSS	BOTTOM ROSS	MONKEY		BOTTOM ROSS	ROSS	ROSS SPLIT	TOP ROSS		TOP ROSS	054
055														055
056		TOP RED ASH	TOP RED ASH		TOP RED ASH	TOP RED ASH		TOP RED ASH	TOP RED ASH	ROSS	ROSS	ROSS	ROSS	056
057														057
058														058
060		RED ASH	BOTTOM RED ASH	RED ASH	BOTTOM RED ASH	BOTTOM RED ASH		BOTTOM RED ASH	RED ASH	RED ASH	RED ASH	RED ASH	RED ASH	060
062														062

ORIGINAL
(red)

AR100091

ORIGINAL (red)

TABLE 10 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD WYOMING VALLEY (CONT'D)

74-144

SEAM CODE \ COLLIERY NAME	PETTEBONE	HENRY-PROSPECT	PEACH-ORCHARD	COLON	DELAWARE PINE RIDGE	HARRY "E"-FORTY FORT	MALTBY-WESTMORELAND	MOUNT LOOKOUT	NO. 14	LAFLIN	PACKER	KEYSTONE	SCHOOLEY	SEAM CODE
010														010
012														012
014														014
016														016
018														018
020														020
022														022
024		SNAKE ISLAND	SNAKE ISLAND		SNAKE ISLAND									024
026	ABBOTT	ABBOTT	ABBOTT		ABBOTT									026
028	KIDNEY	BOWSLEY	KIDNEY		KIDNEY									028
030	HILLMAN	HILLMAN	HILLMAN		HILLMAN		HILLMAN		HILLMAN					030
032	TOP FIVE FOOT	TOP FIVE FOOT	FIVE FOOT		FIVE FOOT	TOP FIVE FOOT	TOP FIVE FOOT		DIAMOND					032
034	BOTTOM FIVE FOOT	BOTTOM FIVE FOOT				BOTTOM FIVE FOOT	BOTTOM FIVE FOOT		TOP CHECKER				TOP CHECKER	034
036														036
038	LANCE	STANTON												038
040	COOPER	UPPER BALTIMORE	COOPER	COOPER	COOPER	FOUR FOOT	FOUR FOOT		BOTTOM CHECKER				CHECKER	040
042	BENNETT BALTIMORE	BALTIMORE, LOWER BALTIMORE	BENNETT	BENNETT	042 BENNETT, 042 BOTTOM PITTSTON	SIX FOOT	042 SIX FOOT, PITTSTON 042 PITTSTON	042 PITTSTON, 042 BOTTOM PITTSTON	PITTSTON		BENNETT	BENNETT	PITTSTON	042
044		CHECKER			CHECKER	TOP ELEVEN FOOT	TOP MARCY	TOP MARCY			CHECKER	CHECKER		044
046														046
048	048 SKIDMORE 048 BOTTOM - SKIDMORE	MARCY	BOTTOM SKIDMORE	MARCY	MARCH	BOTTOM ELEVEN FOOT	MARCY	MARCY	MARCY	MARCY			MARCY	048
050						048 NINE FOOT	048 NINE FOOT							050
054					TOP ROSS	TOP ROSS	TOP ROSS	TOP ROSS	CLARK	TOP ROSS	TOP ROSS	TOP ROSS	TOP CLARK	054
055														055
056	ROSS	ROSS	ROSS		ROSS	BOTTOM ROSS	ROSS-BOTTOM ROSS	BOTTOM ROSS	BOTTOM CLARK	BOTTOM ROSS	ROSS	ROSS	BOTTOM CLARK	056
057					THREE FOOT				TOP RED ASH, BABYLON	TOP BENCH TOP RED ASH	MIDDLE RED ASH	MIDDLE RED ASH		057
058					TOP RED ASH				MIDDLE RED ASH	TOP SPLIT RED ASH	BOTTOM RED ASH	BOTTOM RED ASH		058
060	RED ASH	RED ASH	RED ASH		RED ASH	RED ASH		RED ASH	RED ASH	BOTTOM RED ASH			RED ASH	060
062					"A"				"A"	"A"	"A"	"A"		062

AR100092

TABLE 10 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD WYOMING VALLEY (CONT'D)

74-144

SEAM CODE \ COLLIERY NAME	EWEN	EXETER	BUTLER	STEVENS	SENECA	NO. 8	HEIDLEBERG	FLORENCE	HILLSIDE	WILLIAM "A"	WALLSTEAD	GENERAL	LAGCLIFFE	SEAM CODE
010														010
012														012
014														014
016														016
018														018
020														020
022														022
024														024
026														026
028														028
030			HILLMAN				HILLMAN	HILLMAN	HILLMAN			HILLMAN		030
032														032
034	TOP CHECKER	TOP CHECKER	TOP CHECKER	TOP CHECKER	TOP CHECKER		TOP CHECKER	TOP CHECKER	TOP CHECKER			TOP CHECKER		034
036														036
038														038
040	BOTTOM CHECKER	CHECKER	CHECKER	CHECKER	CHECKER	CHECKER	CHECKER	CHECKER	CHECKER			CHECKER		040
042	PITTSTON	PITTSTON	PITTSTON	PITTSTON	PITTSTON	PITTSTON	PITTSTON	PITTSTON	PITTSTON		PITTSTON	PITTSTON		042
044			TOP MARCY	TOP MARCY	TOP MARCY	TOP MARCY	TOP MARCY	TOP MARCY	TOP MARCY			TOP MARCY		044
046														046
048	MARCY	MARCY	MARCY	MARCY	MARCY	MARCY	MARCH	MARCY	MARCY	MARCY	MARCY	MARCY	MARCY	048
050														050
054	TOP CLARK	TOP CLARK	CLARK, TOP CLARK	CLARK	CLARK	TOP CLARK	CLARK, TOP CLARK	CLARK, TOP CLARK	CLARK, TOP CLARK	CLARK	CLARK	CLARK, TOP CLARK	CHECKER	054
055														055
056	BOTTOM CLARK	BABYLON	BOTTOM CLARK	BOTTOM CLARK	BOTTOM CLARK	CLARK	BOTTOM CLARK	BOTTOM CLARK	BOTTOM CLARK			BOTTOM CLARK		056
057			HIGGER	BABYLON, TOP RED ASH	BABYLON, TOP RED ASH	STARK	HIGGER	HIGGER	HIGGER	TOP RED ASH	NO. 1 DUNMORE	HIGGER	STARK, TOP RED ASH, BABYLON	057
058		FIFTH	FIVE FOOT	FIFTH	FIFTH	MIDDLE RED ASH	FIVE FOOT	FIVE FOOT.	FIVE FOOT	MIDDLE RED ASH	NO. 2 DUNMORE	FIVE FOOT	MIDDLE RED ASH	058
060	RED ASH	RED ASH	BOTTOM RED ASH	SIXTH	SIXTH	BOTTOM RED ASH	BOTTOM RED ASH	BOTTOM RED ASH	BOTTOM RED ASH	BOTTOM RED ASH	NO. 3 DUNMORE	BOTTOM RED ASH	RED ASH	060
062	"A"	RED ASH	NO. 4 DUNMORE, CHINA	CHINA	CHINA		NO. 4 DUNMORE, CHINA	NO. 4 DUNMORE, CHINA	NO. 4 DUNMORE, CHINA	CHINA		NO. 4 DUNMORE, CHINA	CHINA	062

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TABLE 11 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD, LACKAWANNA VALLEY

74 144

SEAM CODE / COLLIERY NAME	OLD FORGE	BRADAWELL	SIBLEY	JERMYN	GREENWOOD	PAYNE	NATIONAL	BAKER	OXFORD	PINE BROOK	DIAMOND	CAPOUSE	VON STORCH	MANVILLE	SEAM CODE
026		EIGHT FOOT			EIGHT FOOT						EIGHT FOOT, OLYPHANT	EIGHT FOOT	EIGHT FOOT	EIGHT FOOT	026
028		FIVE FOOT			FIVE FOOT						FIVE FOOT	FIVE FOOT	FIVE FOOT	FIVE FOOT	028
030	MILLMAN	T30 TOP FOUR FOOT 030 FOUR FOOT B30 BOTTOM FOUR FOOT			T30 TOP FOUR FOOT 030 FOUR FOOT B30 BOTTOM FOUR FOOT	FOUR FOOT	FOUR FOOT	FOUR FOOT	FOUR FOOT	FOUR FOOT	T30 THIRTY INCH 030 FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT B30 BOTTOM FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT B30 BOTTOM FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT B30 BOTTOM FOUR FOOT	030
032		TOP DIAMOND			TOP DIAMOND							TOP DIAMOND	TOP DIAMOND	TOP DIAMOND	032
034	TOP CHECKER	DIAMOND			DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	034
036		TOP ROCK, TOP SPLIT			TOP ROCK, TOP SPLIT						TOP SPLIT ROCK	TOP ROCK, TOP SPLIT	TOP ROCK, TOP SPLIT	TOP ROCK, TOP SPLIT	036
038		ROCK, BOTTOM SPLIT		CHECKER	ROCK, BOTTOM SPLIT	ROCK	ROCK	ROCK	ROCK	ROCK	BOTTOM SPLIT ROCK	ROCK, BOTTOM SPLIT	ROCK, BOTTOM SPLIT	ROCK, BOTTOM SPLIT	038
040	CHECKER														040
042	PITTSTON	BIG	BIG	BIG	BIG	BIG FOURTEEN FOOT B42 FOURTEEN FOOT SPLIT	BIG, FOURTEEN FOOT B42 FOURTEEN FOOT SPLIT	BIG FOURTEEN FOOT B42 FOURTEEN FOOT SPLIT	BIG, FOURTEEN FOOT B42 FOURTEEN FOOT SPLIT	BIG FOURTEEN FOOT B42 FOURTEEN FOOT SPLIT	BIG, FOURTEEN FOOT	BIG	BIG	BIG	042
044	TOP MARCY	TOP NEW COUNTY			TOP NEW COUNTY						TOP SPLIT NEW COUNTY, NEW COUNTY, RIDER	TOP NEW COUNTY	TOP NEW COUNTY	TOP NEW COUNTY	044
046															046
048	MARCY	NEW COUNTY, BIG NEW COUNTY	MARCY	MARCY	NEW COUNTY, BIG NEW COUNTY	NEW COUNTY	NEW COUNTY	NEW COUNTY	NEW COUNTY	NEW COUNTY	BOTTOM SPLIT, NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	048
050															050
054	CLARK, TOP CLARK	CLARK, CHECKER	CLARK	CLARK, ARCHBALD	CLARK, CHECKER	CLARK	CLARK	CLARK	CLARK	CLARK	CLARK	CLARK, CHECKER	CLARK, CHECKER	CLARK, CHECKER	054
055															055
056	BOTTOM CLARK														056
057	NIGGER	NO 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE	UNNAMED	UNNAMED	UNNAMED	UNNAMED	UNNAMED	TOP SPLIT NO. 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE	057
058	FIVE FOOT	NO 2 DUNMORE	FIVE FOOT, STARK	NO 2 DUNMORE	NO. 2 DUNMORE	NO 1 DUNMORE (BS)	NO 1 DUNMORE (BS)	NO 1 DUNMORE (BS)	NO 1 DUNMORE (BS)	NO 1 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	058
060	BOTTOM RED ASH	NO 3 DUNMORE	NO 3 DUNMORE, RED ASH	TOP NO 3 DUNMORE	NO 3 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE	NO. 3 DUNMORE	060
062	NO 4 DUNMORE, CHINA	NO 4 DUNMORE	BOTTOM RED ASH BOTTOM SPLIT RED ASH	BOTTOM NO 3 DUNMORE	NO 4 DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE	NO. 3 DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE CHINA	NO 4 DUNMORE	NO 4 DUNMORE	NO 4 DUNMORE	NO 4 DUNMORE	062

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TABLE 11 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD, LACKAWANNA VALLEY (CONT'D)

SEAM CODE / COLLIERY NAME	[illegible]	DICKSON	CAYUGA	LEGGETTS CREEK	RICHMOND	MARVINE	[illegible]	STORRS	PANCOAST	[illegible]	[illegible]	[illegible]	EDDY CREEK	[illegible]	SEAM CODE
026	EIGHT FOOT, OLYPHANT	EIGHT FOOT		EIGHT FOOT					EIGHT FOOT	EIGHT FOOT		EIGHT FOOT		EIGHT FOOT	026
028	FIVE FOOT	FIVE FOOT		FIVE FOOT					FIVE FOOT	FIVE FOOT		FIVE FOOT		FIVE FOOT	028
030	T30 [illegible] ROCK 030 FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT 030 BOTTOM FOUR FOOT	FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT 030 BOTTOM FOUR FOOT	FOUR FOOT	FOUR FOOT		FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT 030 BOTTOM FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT 030 BOTTOM FOUR FOOT	FOUR FOOT	T30 TOP FOUR FOOT 030 FOUR FOOT 030 BOTTOM FOUR FOOT	DIAMOND	T30 TOP FOUR FOOT 030 BOTTOM FOUR FOOT	030
032		TOP DIAMOND		TOP DIAMOND					TOP DIAMOND	TOP DIAMOND		TOP DIAMOND		TOP DIAMOND	032
034	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	DIAMOND	ROCK	DIAMOND	034
036	TOP SPLIT ROCK	TOP ROCK, TOP SPLIT		TOP ROCK, TOP SPLIT					TOP ROCK, TOP SPLIT	TOP ROCK, TOP SPLIT		TOP ROCK, TOP SPLIT		TOP ROCK, TOP SPLIT	036
038	BOTTOM SPLIT ROCK	ROCK, BOTTOM SPLIT	ROCK	ROCK, BOTTOM SPLIT	ROCK	ROCK	ROCK	ROCK	ROCK, BOTTOM SPLIT	ROCK, BOTTOM SPLIT	ROCK	ROCK, BOTTOM SPLIT	RIDER	ROCK, BOTTOM SPLIT	038
040															040
042	018, FOURTEEN FOOT	018	042 018, FOURTEEN FOOT 042 FOURTEEN FOOT SPLIT	018	042 018, FOURTEEN FOOT 042 FOURTEEN FOOT SPLIT			042, 018, FOURTEEN FOOT 042 FOURTEEN FOOT SPLIT	018	018	018, FOURTEEN FOOT 042 FOURTEEN FOOT SPLIT	018	042 TOP SPLIT FOURTEEN FOOT 042 BOTTOM SPLIT FOURTEEN FOOT	018	042
044	TOP SPLIT NEW COUNTY, NEW COUNTY, RIDER	TOP NEW COUNTY		TOP NEW COUNTY					TOP NEW COUNTY	TOP NEW COUNTY		TOP NEW COUNTY		TOP NEW COUNTY	044
046															046
048	BOTTOM SPLIT NEW COUNTY	NEW COUNTY BOTTOM NEW COUNTY	NEW COUNTY	NEW COUNTY BOTTOM NEW COUNTY	NEW COUNTY	NEW COUNTY	NANCY	NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	BOTTOM NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	048
050															050
054	CLARK	CLARK, CHECKER	CLARK	CLARK, CHECKER	CLARK	CLARK	CLARK	CLARK	CLARK, CHECKER	CLARK, CHECKER	CLARK	CLARK, CHECKER	CLARK	CLARK, CHECKER	054
055															055
056															056
057	TOP SPLIT NO. 1 DUNMORE	NO. 1 DUNMORE	"UNNAMED"	NO. 1 DUNMORE	"UNNAMED"	NO. 2 DUNMORE	SUPER DUNMORE	"UNNAMED"	NO. 1 DUNMORE	NO. 1 DUNMORE	"UNNAMED"	NO. 1 DUNMORE	NO. 1 DUNMORE	NO. 1 DUNMORE	057
058	NO. 1 DUNMORE	NO. 2 DUNMORE	NO. 1 DUNMORE(D.S.)	NO. 2 DUNMORE	NO. 1 DUNMORE (DS)	NO. 3 DUNMORE	NO. 1 DUNMORE	NO. 1 DUNMORE(D.S)	NO. 2 DUNMORE	NO. 2 DUNMORE	NO. 1 DUNMORE (DS)	NO. 2 DUNMORE	TOP SPLIT NO. 3 DUNMORE	NO. 2 DUNMORE	058
060	NO. 2 DUNMORE	NO. 3 DUNMORE	NO. 2 DUNMORE	NO. 3 DUNMORE	NO. 2 DUNMORE	BOTTOM SPLIT NO. 3 DUNMORE	NO. 2 DUNMORE	NO. 2 DUNMORE	NO. 3 DUNMORE	NO. 3 DUNMORE	NO. 2 DUNMORE	NO. 3 DUNMORE	BOTTOM SPLIT NO. 1 DUNMORE	NO. 3 DUNMORE	060
062	NO. 3 DUNMORE CHINA	NO. 4 DUNMORE	NO. 3 DUNMORE	NO. 4 DUNMORE	NO. 3 DUNMORE	NO. 4 DUNMORE	NO. 3 DUNMORE	NO. 3 DUNMORE	NO. 4 DUNMORE	NO. 4 DUNMORE	NO. 3 DUNMORE	NO. 4 DUNMORE	NO. 4 DUNMORE	NO. 4 DUNMORE	062

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TABLE 11 COAL SEAM CORRELATION CHART NORTHERN ANTHRACITE FIELD, LACKAWANNA VALLEY (CONT'C)

74-144

SEAM \ COLLIERY NAME	GRASSY ISLAND	STERRICK CREEK	LACKAWANNA	PECK SHAFT	RIVERSIDE	RAYMOND	GRAVITY SLOPE	FERNYN	ERIE	POWDERLY	COAL BROOK	GIBSON	FOREST CITY	CLINTON	STILLWATER	SEAM CODE
026	EIGHT FOOT	EIGHT FOOT														026
028	FIVE FOOT	FIVE FOOT														028
030	T30 TOP FOUR FOOT 030 BOTTOM FOUR FOOT	T30 TOP FOUR FOOT 030 BOTTOM FOUR FOOT	FOUR FOOT													030
032	TOP DIAMOND	TOP DIAMOND														032
034	DIAMOND	DIAMOND	DIAMOND													034
036	TOP ROCK, TOP SPLIT	TOP ROCK, TOP SPLIT														036
038	ROCK BOTTOM SPLIT	ROCK BOTTOM SPLIT	ROCK	ROCK												038
040																040
042	BIG	BIG	042 BIG FOURTEEN FOOT 042 FOURTEEN FOOT SPLIT	T42 TOP GRASSY 042 GRASSY			GRASSY	GRASSY		GRASSY	GRASSY		GRASSY			042
044	TOP NEW COUNTY	TOP NEW COUNTY		NEW COUNTY		RIDER NO 1										044
046						RIDER NO 2										046
048	NEW COUNTY BOTTOM NEW COUNTY	NEW COUNTY, BOTTOM NEW COUNTY	NEW COUNTY	CLARK RIDER		RIDER NO 3	NEW COUNTY	NEW COUNTY		NEW COUNTY				GRASSY, NEW COUNTY		048
050						RIDER NO 4										050
054	CLARK CHECKER	CLARK CHECKER	CLARK	CLARK		CLARK	ARCHBALD	CLARK	CLARK	TOP CLARK	T54 TOP CLARK 054 CLARK	T54 TOP CLARK 054 CLARK	T54 TOP CLARK	T54 TOP CLARK		054
055				T55 TOP NUDAR 055 BOTTOM NUDAR												055
056										BOTTOM CLARK	BOTTOM CLARK		BOTTOM CLARK	BOTTOM CLARK		056
057	NO 1 DUNMORE	NO 1 DUNMORE	UNNAMED	NO 1 DUNMORE	NEW COUNTY	NO 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE		THIRD BED	NO 1 DUNMORE	NO 1 DUNMORE	NO 1 DUNMORE			057
058	NO 2 DUNMORE	NO 2 DUNMORE	NO 1 DUNMORE	NO 2 DUNMORE	TOP CLARK	NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE			NO 2 DUNMORE	NO 2 DUNMORE	NO 2 DUNMORE	RING		058
060	NO 3 DUNMORE	NO 3 DUNMORE	NO 2 DUNMORE	NO 3 DUNMORE	CLARK	NO 3 DUNMORE	NO 3 DUNMORE		NO 3 DUNMORE	DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE	NO 3 DUNMORE	TOP CLIFFORD		060
062	NO 4 DUNMORE	NO 4 DUNMORE	NO 3 DUNMORE		DUNMORE									CLIFFORD	CLIFFORD	062

2.5 CLASSIFICATION PROGRAM DEVELOPMENT

2.5.1 Considerations. The general items for consideration in the development of a subsidence potential classification program include a)the accuracy and format required in the output product b)the functions and performance characteristics of the classifier algorithm and c)the character and volume of the required input data. As described in previous sections, the output format desired was a map output at 1:24,000 scale which provided the potential classification of each 40 acre land element in the Anthracite region defined by the USGS-7 1/2' quadrangle map-based grid system (See Section 2.2.2.). In particular, each land element was to be classified as being in one of three categories:

Class 1 - "Precautionary Area" future subsidence probable if subsidence has not already progressed to completion. Site engineering recommended.

Class 2 - Subsidence possible. $S_{MAX} > 0 <$ 0.5 feet. Site engineering recommended.

Class 3 - No subsidence. $S_{MAX} = 0.0$ feet.

In addition, some indication was to be presented on the output product of the magnitude of the maximum vertical displacement possible should subsidence occur along with a reason-indicator (as to why each element was adjudged as belonging to a specific class). These output format specifications were developed jointly with the planning contractors associated with the overall subsidence program who would be utilizing the map output. By developing them in this way a useful product directly acceptable was produced for direct incorporation into the users general practices.

Since the resultant maps were to be utilized in gross assessments of risk, the impact associated with miscalassifications would be minimized if a worst case analysis were applied. This consideration was therefore factored into the design of the classification algorithm and as indicated in Section 2.3.1.3 was carried through into the information synthesis and data base development activities.

In view of these output specifications, three potential models or classification algorithms were considered for use in this study, i.e. finite differences, semi-empirical and engineering judgment. Each of these methods are discussed briefly below, along with a summary of their comparative ratings with regard to the performance characteristics of accuracy, cost, and acceptance by Mining Engineers.

The finite difference technique depends on detailed descriptions of the physical site to be modelled. In the case of a mine for example, this description would include the dimensions of the rooms, tunnels, and pillars and the specific composition of the overburden over the entire 40 acre elemental area. This information would be used as initial conditions for the finite difference scheme which would be stepped in time by short increments applying the modelled physical laws of rock mechanics to trace the changes occurring in the basic mine configuration. Such a technique if supported by detailed knowledge of the erosion effects caused by mine pool interaction with the support pillars, would theoretically provide the most complete results in terms of the spatial extent of the subsidence effect and the magnitude of vertical displacement as a function of time.

Isenberg[14] described a finite difference computer model for analyzing cavities in rock. The model outputs were compared with measurements made during excavation of a cavity in Colorado. The spacing of points used to input the model were relatively fine (15 feet apart) and the computer run experienced were very large in order to keep the time steps small enough to maintain mathematical stability. Even with this effort, the results were not particularly good.

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Achievement of these limited results was extremely costly and certainly prohibitive in a practical sense if considered over an area of the size of the Anthracite Region. The inavailability of the input data at the level of detail required and the magnitude of the data management problems involved made this approach untenable.

Consideration was therefore given to a Semi-empirical model based on studies documented by the British National Coal Board. This data was obtained during extensive experience with planned controlled subsidence; a technique utilized above active long wall mines. The measurements and semi-empirical analytical models developed in this activity have been compiled along with other data in the "Subsidence Engineers' Handbook"[1] A brief summary of the empirical formulae in this technique has been given in Section 2.1 of this report. These analytical techniques although intended for use in predicting planned subsidence over long wall mines, has proven useful in predicting the spatial component of subsidence in the Anthracite Region. Engineers with the Pennsylvania Department of Environmental Resources have used similar techniques[2] to predict maximum subsidence in sites being considered as potential school sites. The use of this semi-empirical model although certainly more tractable than the rigorous finite-difference approach again required extensive detail about the rooms and pillar configuration of each mine as well as specific empirical data on the interaction between underground mine pool water and coal pillars in the Anthracite Region. The potential cost of applying this technique to an area the size of the Anthracite Region was also of considerable magnitude. As a result of these considerations, attention was concentrated on identifying the specific parameters that would enable one to characterize a mined area as vulnerable or not vulnerable to subsidence effects. A list of parameters and criteria (See Section 2.2.1) therefore was

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developed which summarized those conditions most associated with subsidence prone areas. This set of critical parameters and criteria was compiled by the investigation of the empirical data available and draws on the engineering experience of consulted mining engineers. A logical test of each of these parameters and an evaluation of the specific conditions relative to these factors in each land area considered could then validly be used as a means for classifying the area as to subsidence potential. Investigation of the costs of implementation and application of such a systematic engineering assessment algorithm were favorable. In addition, the data base required to support such an algorithm appeared manageable in terms of collection and maintenance.

A summary of the relative assessments of each approach with regard to accuracy, cost and acceptance is presented in Table 12. On this basis, the Systematic Engineering Assessment approach was chosen for implementation and a computer program called SEAMS (Singer Engineering Assessment of Mine Subsidence) was developed.

TABLE 12 SUBSIDENCE MODEL CONSIDERATIONS AND TECHNIQUES

74-144

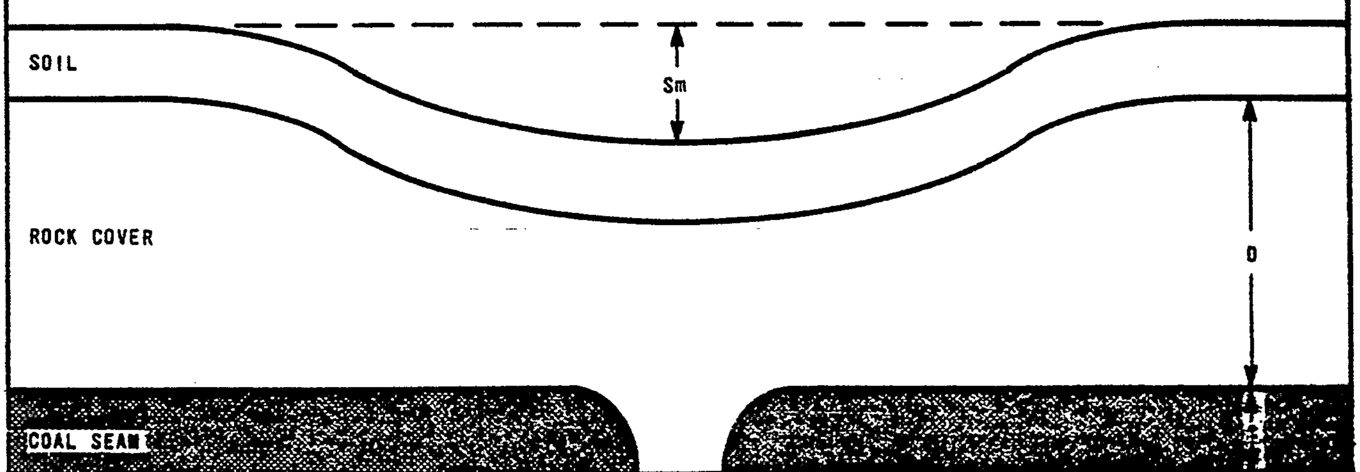
CONSIDERATION	COMPONENT	MODELING TECHNIQUES		
		FINITE DIFFERENCE	SEMI-EMPIRICAL	ENGINEERING ASSESSMENT
ACCURACY	SPATIAL	GOOD	GOOD	GOOD
	MAGNITUDE	GOOD	FAIR	FAIR
	TIME	FAIR	POOR	POOR
COST	MATHEMATICS	FAIR	FAIR	GOOD
	PROGRAMMING	POOR	FAIR	GOOD
	KEYPUNCHING	GOOD	GOOD	GOOD
	COMPUTER INPUT DATA AVAILABILITY	POOR	POOR	GOOD
	MAP PRODUCTION	POOR	GOOD	GOOD
	COMPUTER TIME	POOR	FAIR	GOOD
ACCEPTANCE	MINING ENGINEERS	POOR	FAIR	FAIR
	PLANNERS	GOOD	GOOD	GOOD

2.5.2 Model Development (SEAMS). Once the parameters associated with subsidence prone areas were identified, an assessment of their relative criticality was made. Engineering experience was utilized to arrive at a technique for systematic assessment of conditions in each mapped elemental area. Based on the values of the critical parameters characterizing each land area, the element was placed into one of three classes reflecting the likelihood of seam collapse. This preliminary classification was then combined with the total maximum subsidence (TSm) calculated by the empirical relation given in Figure 18, to obtain a final subsidence potential classification of 1, 2, or 3.

This formula estimates the deepest point in a subsidence trough after the collapsed cavity has been filled. The .9 factor at the beginning of the formula accounts for the incomplete packing of the cavity. In other words the material falling into the cavity will occupy only 90 percent of the cavity for it will be in an unconsolidated form.

The seam thickness, t, gives the vertical dimension of the cavity to be filled. The next two terms, .01D and f(W/D), are empirically derived factors[1] that account for the bridging and packing of materials above the rupture. These two factors account for the negative correlation between deep and narrow cavities and the effect at the surface.

Note that the maximum subsidence (Sm) in Figure 18 gives a value for a single seam. For multiple mined seams under an area the summation of the maximum subsidence gives, by the law of superposition,



$\boxed{Sm = .9\,(t - .01D)\,f(W/D)PF}$, $Sm \geq .01$

$Sm = .01$, $0. < Sm < .01$

$Sm = 0.$, $Sm \leq 0.$

WHEREIN:

- t = SEAM THICKNESS
- D = DEPTH EXCLUDING SOIL
- W = WIDTH (SPAN)
- P = PERCENT EXTRACTION
- F = 1.0 FOR UNTREATED SEAMS
  = 0.6 FOR FLUSHED, STOWED, OR BACKFILLED SEAMS

f(W/D) (((2.15909 *W/D-6.26136)*W/D
+5.51136)*W/D - .469091)*W/D , W/D<1.2

f(W/D) = 1 , W/D≥1.2

$TS_m = \sum_i S_{mi}$, i = 1 TO NUMBER OF COAL SEAMS

MAXIMUM SUBSIDENCE (Sm)
TOTAL MAXIMUM SUBSIDENCE (TS_m)

FIGURE 18 MAXIMUM SUBSIDENCE MODEL

74-144

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a maximum subsidence (TSm, total maximum subsidence) if every seam collapses. This total is outputted from the model both on the summary data listings (see Figure 20) and the subsidence potential maps which reflect the magnitude of subsidence that could occur.

This total, however, does not indicate the likelihood of a mined seam collapsing. Useful analytical or even empirical work in predicting the collapse of pillars or caving in the roof of a long abandoned mine appears to be non-existent.[20] In place of such work engineers' judgements are used. These judgements need to be used in estimating the rate of deterioration of the pillars and the effects of occasional heavy loading from floods.

Specifically, the algorithm developed for performing this systematic classification operates in the following manner. Each element is tested as to the level of extraction in each coal seam below the element and the degree of stripping within the element. (See Table 13, Model Step 1). If these conditions indicate no extraction or that the mined seams have been totally stripped, the element is given the lowest likelihood of seam collapse (Class 3). If the conditions indicate subsurface cavities, the algorithm interrogates the data base at step 2.

In step 2 if three conditions are met simultaneously, the collapse class will be 1. The first of these conditions is that the rock cover over the top seam is less than 100 feet. The second condition further requires that this rock cover is faulted or jointed. The cover would thus be weak and relatively thin. Added to this is the third condition that the mine pool is higher than the top seam. Although some contend the water gives support to the mine roof, the engineers on this study theorize

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TABLE 13 SUBSIDENCE POTENTIAL DETERMINATION 74-144					
COLLAPSE CLASS	MODEL STEP	COLLAPSE REASON CODE #	COLLAPSE REASON	TOTAL MAXIMUM SUBSIDENCE	VULNERABILITY CLASS
1	2	1	TOP ROCK COVER LESS THAN 100' AND FAULTED OR JOINTED ROCK CONDITION AND MINE POOL GREATER THAN TOP OF SEAM	TSm>0.5 0.1≤TSm<0.5 TSm = 0.0	1 2 3 (X)
	3	2	TOP ROCK COVER LESS THAN 50'		
	4	3	WIDTH/DEPTH GREATER THAN .25		
2	5	4	MINE PILLAR DIMENSION LESS THAN 30'	TSm >0.0	2
	6	5	.10 ≤W/D ≤ .25	TSm = 0.0	3 (Y)
3	1	6	NO EXTRACTION OR STRIPPED		3
	7	7	LESS THAN 50% EXTRACTION ON EVERY SEAM		
	8	8	WIDTH/DEPTH LESS THAN .10		

the water will lubricate a weak overburden and interact with the mine pillars thereby adding loading to the roof on any lowering of the mine pool. These conditions then, if all present, lead to a collapse assessment of class 1.

If the conditions in step 2 are not met, the algorithm moves to step 3. Herein if the rock cover over the top seam is less than fifty feet, the collapse class becomes 1, for pot-hole subsidence is likely.

If the top rock cover is not less than fifty feet, step 4 is taken next. The width of the seam to the depth of seam ratio (W/D) is compared to an empirical threshold of .25 for each seam from top down. If this ratio is less than .25, then the possible subsidence damage is assessed as negligible.[17] Inversely if the

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ratio is greater than .25 for any seam, the element is put in a collapse class of 1, since subsidence damage due to this seam is likely if it should collapse.

If the algorithm finds the element not to be in collapse class 1 for any of the above reasons, it moves on to step 5 to evaluate if it belongs to class 2. If the minimum pillar dimension is less than 30 feet, collapse is possible and the collapse likelihood class is stated to be 2.

Based on past empirical data, if the pillar dimension is larger than 30 feet but the W/D for any seam is greater or equal to .10, collapse is also possible. If this condition exists the algorithm again assigns a collapse class of 2.

If the algorithm finds the element meets none of the conditions leading to a collapse likelihood class of 1 or 2, the class is automatically assigned as 3, since none of the conditions experimentally observed in subsidence prone areas are met. The algorithm, however, does extract additional information from the data base by checking every seam for less than 50 percent extraction. If this is the case a reason of 7 is given for the selection of class 3.

If this is not the case the algorithm at step 8 will assign reason 8 to the classification to reflect the fact that W/D was less than .10. If this were not true the element would have been a class 1 in step 4 or a class 2 in step 6, and this is the controlling condition for classifying the element as stable.

After assigning a collapse likelihood class in this manner, the algorithm examines the total maximum subsidence (TS_m) to determine if the collapse of all

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the cavities below the element will subside the surface. If there is no predicted surface subsidence (TS_m = 0.0 feet), then the subsidence potential classification becomes 3. If the collapse class is 1 and the total maximum subsidence relatively small (between .1 and .5 feet), then the potential classification becomes 2. In other cases the collapse likelihood class becomes the subsidence potential class, except in those elemental areas that have experienced complete flushing. In this event the algorithm assigns a class 2 or 3 to the element depending on the value of the total S_{max} calculation. Figure 19 represents a flow diagram of the seams algorithm operation.

An example of the algorithm operation is given for the element described in the data listing shown in Figure 20.

Step

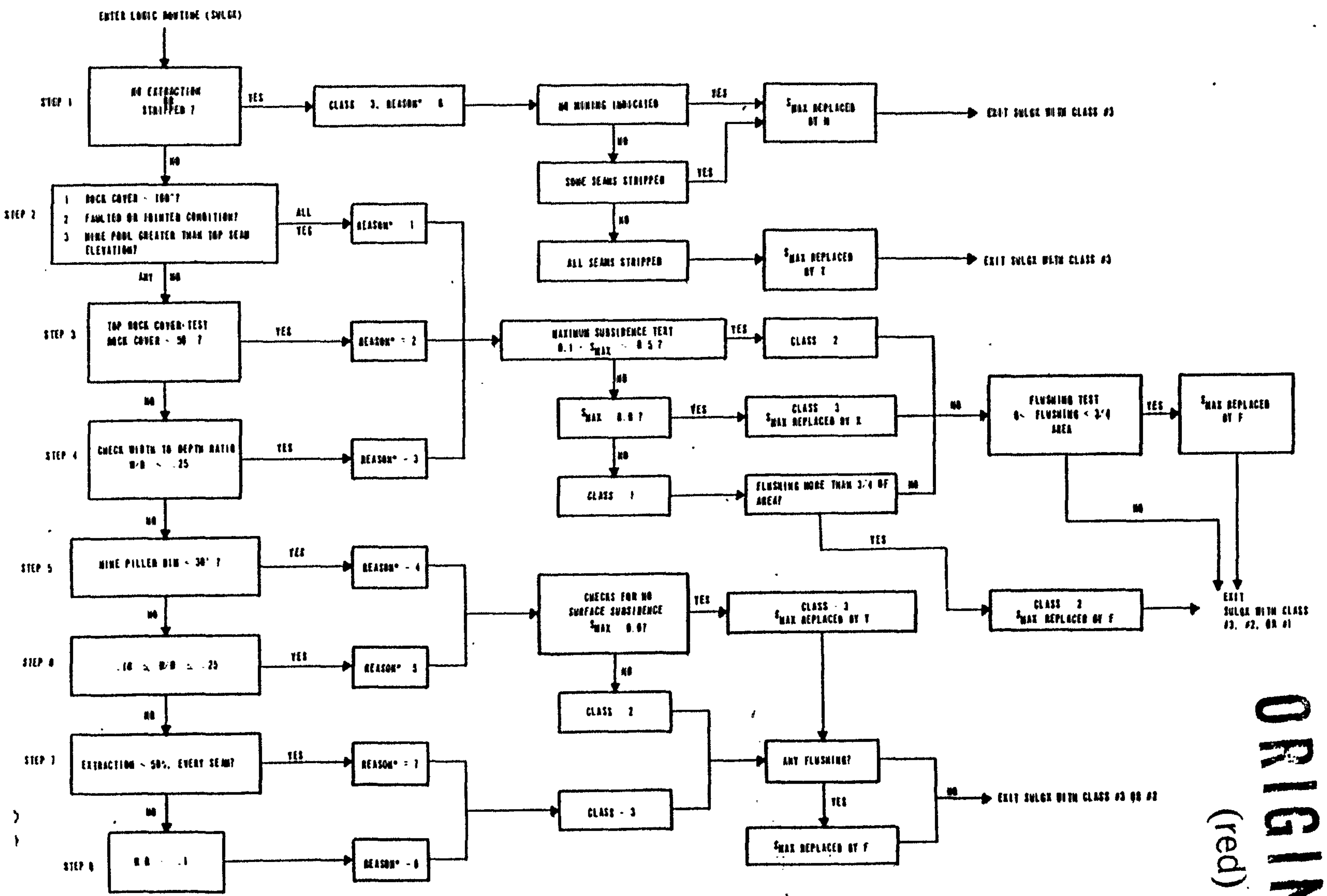
1 - There has been extraction in all five seams - the model moves to the next test.

2 - The top rock cover of 141 feet is greater than 100 feet - the model moves on to the next evaluation.

3 - The top rock cover is greater than 50 feet - the model moves to the next consideration.

4 - The W/D for seam 024 is less than .25; however, the next seam 026 has a W/D greater than .25. (For all tests the seams are taken from the top downward.) The model stops at this point and assigns a collapse likelihood class of 1.

Next the model checks the total S MAX and since it is greater than 0.5 feet, a subsidence potential class of 1 is assigned to the element with reason code 4 indicated.



*REASONS ARE EXPLAINED IN TABLE 13

FIG 10 SEAMS FLOW DIAGRAM

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LOCATION WBW232

SURFACE ELEV	707
SOIL THICKNESS	7
FLOOD LEVEL	560
POOL LEVEL	521
RELIEF	B
POPULATION	E
REAL ESTATE VAL	
SUBSIDENCE (YR)	?

SEAM CODE	THICKNESS	ELEV	%EXTRAC	LAST MINED	DIP	ROCK COVER	ROCK INTEG	MIN PIL DIM	PIL AREA	COLL-APSE	W	BACK FILL	LITH	COND	DEPTH (D)	W/D	PP	PW/T	PW/D	S MAX
024	04	555	D	38	21SE	141		B	B	?	15	N	A	A	141	0.11	194.	6.	0.18	0.01
026	05	375	A	38	25SE	175		A	A	?	400	N	A	A	320	1.25	7040.	10.	0.16	1.54
028	07	303	A	35	15SE	65		A	A	?	300	N	A	A	390	0.77	8580.	7.	0.13	2.14
030	07	211	D	26	18SE	85		A	A	?	10	N	B	A	482	0.02	663.	7.	0.10	0.00
042	08	-169	D	54	20SE	372		B	A	?	20	N	A	A	861	0.02	1184.	3.	0.03	0.01

TOT. 3.70

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74-144

FIG. 20 ELEMENTAL AREA DATA LISTING

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Overall, the algorithm combines collapse likelihood with the empirical calculation of total possible subsidence should collapse occur to result in a systematic assessment of vulnerability to subsidence. Cases will arise wherein the probability of collapse of a seam is high and, because the seam is narrow and deep, its collapse would result in no subsidence at the surface. The model in these cases will show low potential, i.e. class 3. . One must note, however, that the calculation of total maximum subsidence includes all seams, not just those prone to collapse. Its use in the model in this manner makes the model a worst case situation classification scheme. This fact should be kept in mind while using or interpreting the impact of the classification maps produced by this algorithm.

2.5.3. Programs (SEAMS). Computer programs written in FORTRAN language were developed to enter keypunched subsidence data onto a disk pack, process data on a PDP 11/45 computer, and produce a variety of outputs. The programming system uses what may be termed a menu. The menu (Table 14) has a wide variety of parameters that may be easily modified for any particular program. Typically, on many runs a menu will appear on the computer cathode ray tube (CRT). The programmer changes the menu and after a program or set of programs is executed, the menu is redisplayed on the CRT. The programs have been classified and summarized in Table 15.

Execution times for various outputs are:

Status Map	35-55	sec./map
CRT Map	20-30	sec./map
Listing	.7	sec./Element
Director	45	min.

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HRB-SINGER DATA ANALYSIS

```
 1 PROC NAME            =SUB2.LDA
 5 ZERO                 =    0
 6 QUAD (ALL=ALL)       =WBW
 8 SEC (-1=ALL)         =    2
 9 ELEM ROW(Z=ALL)      =Z
10 ELEM COL (-1=ALL)    =   -1
11 CUR QUAD             =
13 CUR COL,ROW          =    0      0
15 MAP ROUTINE          =    1
16 MAP PARAMETER        =  290
17 MAP VALUE            =
18 -1 ON END            =    0
19 COMMENT IX,IY        =  200     20
21 OUTPUT UNIT          =    5
22 LOWER LEFT           =  100     60
COMMAND:
```

TABLE 14 COMPUTER PROGRAM MENU FOR SUMMARY DATA LISTING BY SECTION AND ELEMENT; I.E. MENU IS SET TO RUN WBW2, ALL ELEMENTS

74-144

2.5.4. Output. A variety of outputs are possible from the subsidence programs. Some of the output displays were designed for use by subsidence investigators while other output displays were created for programmers involved in developing the software or for HRB-Singer, Inc. analysts studying the subsidence related data.

2.5.4.1. Diagnostics. Several programs contain the capability to communicate abnormal problems in the data or the computer system to the programmer. Certain kinds of keypunching errors were identified as well as cases where data could not be located on the storage disk. In addition, hardware problems, such as failure to read the disk correctly were monitored.

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TABLE 15 SUBSIDENCE COMPUTER PROGRAMS (red)

74-144

TYPE	NAME	INPUT	OUTPUT	COMMENTS
MANIPULATION	ADISC	AMOUNT OF DATA DESIRED TO BE STORED.	IF ROOM ON DISK EXISTS, THE STORAGE LOCATION IS RETURNABLE.	
	CHASE			LINKS DATA ON DISK.
	CODONE	ELEMENT ID	MOVE DATA ON HEADER CARD.	CHECKS FOR SOME KINDS OF KEYPUNCH ERRORS.
	CODROW	ELEMENT ID	MOVE DATA ON SEAM CARD.	CHECKS FOR SOME KINDS OF KEYPUNCH ERRORS.
	STORE	DATA FOR AN ELEMENT FROM SUBIN.		ACTUALLY PUTS SUBSIDENCE DATA ON DISK.
	SUFI	ELEMENT ID	DISK LOCATION	FINDS LOCATION OF DATA BY ELEMENT ON DISK.
	TABA			MODIFIES DATA DIRECTORY
	TABF			SEARCHES DATA DIRECTORY
MAIN PROGRAMS	SUBIN			CALLS CARDIN WHICH READS DATA CARDS AND STORE WHICH PUTS THEM ON DISK.
	SUBLP		DIRECTORY LISTING	
	SUB1	COMPUTER SWITCHES	MENUS	MOST PROGRAMS RUN FROM MENU.
	SUB2	1. OUTPUT DEVICE I.E. LINE PRINTER, MAGNETIC TAPE. 2. LISTING OR MAP OPTION.	ALL DATA BY ELEMENT OR ONE DATUM FOR EVERY ELEMENT (MAP)	MAPS POPULATION, RELIEF ETC., ON CRT OR LISTS ALL SUCH DATA FOR ELEMENTS WITH ALL SEAM DATA. IF OUTPUT DEVICE IS MAGNETIC TAPE, LISTING IS STORED FOR LATER USE.
	SUB9	QUADRANGLE NAME	MAP ON STATOS PRINTER/PLOTTER WITH SMAX, CLASS, PREVIOUS SUBSIDENCE, REASON.	
DATA PROCESSING	CALC	DATA FROM DISK FOR ONE ELEMENT.	D, W·D, PP, PW/T, PW/D	
	SMAX	DATA FROM DISK FOR ONE SEAM.	MAXIMUM SUBSIDENCE.	
	SUCA	DATA FROM DISK FOR ONE ELEMENT.	CONVERTS DATA CODES TO REAL NUMBERS.	
	SUFD	SMAX BY SEAM	COMPUTES TOTAL MAXIMUM SUBSIDENCE	
	SULGX	EXTRACTION, ROCK COVER MINE POOL ETC.	VULNERABILITY CLASS.	
OUTPUT PROGRAMS	ROWHED	ELEMENT ID	HEADINGS FOR SEAM LISTING.	
	ROWOUT	ELEMENT ID	WRITES AND SPACES SEAM DATA.	
	SUGR	SECTION ID	MAKES MAP ON CRT.	
	SUST	SECTION ID	PRINTS MAP ON STATOS PRINTER/PLOTTER.	OUTPUT PROGRAM FOR SUB9.
	WRTONE	ELEMENT ID	WRITES SUMMARY DATA FOR SECTION ON LISTING.	

ORIGINAL
(red)

2.5.4.2. Directory. A listing of all the elements (from north to south and west to east) with their precise location on the disk was made at various times in the project. The purpose was to enable programmers to solve a number of data handling problems.

2.5.4.3. Maps - Risk/Potential. Subsidence risk, reason for classification, maximum subsidence and subsidence history are shown on maps produced by the Statos Printer/Plotter. Examples and an explanation of these maps are found in volumes 2 and 3.

2.5.4.4. Maps - Related Data. It is possible to produce maps of additional elemental data on the computer CRT. Information such as relief, population, and soil thickness is available for analysts to call for a fast snapshot view. Maps are not of publication quality but are fast and inexpensive. Interactive capabilities of the computer are taken advantage of in order to permit an operator to rapidly adjust map parameters or change mapped locations.

2.5.4.5. Summary Data Listing. Summary data for each element and every mined seam in that element can be displayed. One display option is printed on paper from a line printer and an example is shown in Figure 20. It is possible to put the same data on a Vector General Refresh Scope. No hard copy is then available but execution is 12 times faster. The summary data may also be put on a tape in order to utilize faster printers which are available.

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Abbreviations and data dimensionality are discussed in Section 2.3.2. Calculations made from the data by the computer and printed on the Summary Data Listings are as follows:

Depth (D)	Distance in feet from the surface
W/D	Width to depth ratio
PP	(1.1 X D/(100-% Extraction) X .01) Pillar Pressure in pounds per square inch (PSI) At 2000 PSI pillars normally are unable to support weight. (See reference 17)
PW/T	Minimum Pillar Dimension to Seam Thickness ratio
PW/D	Minimum Pillar Dimension to depth ratio
S_{max}	Maximum Subsidence for the particular seam

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3. RESULTS

3.1 SUMMARY

This study was directed toward establishing criteria and evaluation techniques for the prediction of subsidence potential and presentation of such potential classifications in a manner convenient for subsequent risk evaluations.

A major portion of the activity comprised the inspection of existing mining information, extraction of the parameters pertinent to the subsidence consideration, and the synthesis of this information into an interactive computer data base.

To keep this effort within practical limits a resolution size of approximately 40 acres was established based on a U.S.G.S. survey 7 1/2 minute quadrangle grid system wherein each quadrangle was divided into nine 2 1/2 minute sections and each section further divided into 100 elements. Data was collected for each forty acre element from mine map folios, mine maps not incorporated in mine map folios, U.S.G.S. geologic quadrangle map series, coal investigation map series, special investigation map series, the Second Pennsylvania topographic and geologic survey bulletins, aerial photography, and the topographic quadrangles themselves.

Data was collected for 25 key critical parameters and entered into the computerized data base. Engineering experience was utilized to develop an algorithm which would provide for systematic assessment of conditions in each mapped elemental area. Based on the values of the critical parameters characterizing each elemental land area, one of three class numbers were assigned by the computer reflecting the likelihood of seam collapse. In addition, the magnitude of the maximum vertical displacement possible should subsidence occur was calculated along with a reason-indicator for the class assignment decision. Overall, the algorithm combines collapse likelihood with the empirical calculation of total possible subsidence should collapse occur in all mined seams to result in a systematic assessment of potential to subsidence. The use of the total maximum subsidence calculation makes the model a worst case situation classification scheme.

Portions of twenty of the thirty-six U.S.G.S. 7½ minute quadrangle defining this study are included in the subsidence potential classification for each elemental area. The remaining maps give some indication of past mining history by reporting stripping, deep mining, robbing, no mining, and combinations of the above.

The algorithm was exercised on a total of 3106 elements in the Northern field, 880 elements in the Western Middle Field, and 295 elements in the Southern Field. In the Northern Field the algorithm was exercised for all collieries except the Stackhouse Colliery lying west of the Susquehanna River on the Shickshinny quadrangle. With the one exception of the Stackhouse Colliery (less than 1% of the total number of elements) the Northern Field was completely included in the PDP 11/45 computer data base.

Testing of the algorithm occurred in two areas of the Bituminous coal field of Appalachia. Thirteen elemental areas over single seam mines in western Centre County, Pennsylvania yielded a distribution of 6 elements in class 1, 6 elements in class 2, and one element in class 3 (See table 18 section 3.3.3). Twenty elemental areas over single and two seam mines in western Allegany County, Maryland yielded twenty class 1 elements with maximum subsidence varying from 4.3 feet to 9.1 feet (See table 18 section 3.3.3).

Extensive correlation of coal seams in the Northern Anthracite Field contribute to the usefulness of the data base. Additional map displays and statistical information may be derived from the data base which is designed for continuous update and the addition of new parameters.

3.2 LIMITATIONS

The SEAMS algorithm classifies subsidence potential for forty acre land areas on a worst case basis and is therefore limited to use in regional planning activities. One of the major limitations of the algorithm is the element by element calculation of subsidence potential without taking into account the effect of adjacent elements. Each element is classified on the criteria contained within the element and is based on the worst mining conditions present in as little as ten percent of the total element. The effect of adjacent stable conditions, adjacent barrier pillars, adjacent no mining, etc. is not considered in the class calculation for a given element.

Although data on the condition of the land surface was collected, the algorithm does not consider the effect of static or dynamic loading. The effect of extensive land development or the effects of flooding are excluded from consideration.

The strength of the rock cover (rock integrity) was not included in the calculation although its condition was. The prediction of the ability of the roof rock to withstand collapse is not yet a quantified science. Therefore the rock cover is treated uniformly regardless of lithology. This limitation can readily be corrected once such a collapse resistance relationship is established by the introduction of a numerical factor into the algorithm. The necessary lithologic information for use in such a calculation is present in the data base.

The algorithm does not consider the time factor in calculating subsidence potential. For example no regard is given to the deterioration of pillars through time nor to the fact that many of the mines depicted in maps fifty or more years old may have already collapsed.

The accuracy of the old mining maps from which data have been extracted is questionable in light of the many changes that may have occurred since their drafting. Subsequent extraction through robbing of pillars and recent strip mining is not reflected in the algorithm. Nevertheless they represent the most complete data available on the extent of past mining and mining practices in the Anthracite Region.

The algorithm is designed primarily for predicting subsidence in low dip strata as in the Northern Field. The elevation shift used in the highly folded strata of the southern anthracite fields was instituted as a means to standardize the method of determining the depth to the coal seams. The dip angle of the strata is not used in the algorithm, however, the angles themselves are in the data base. The algorithm is therefore limited in its usefulness in these highly folded rock areas. Continued model development is needed with regard to these limitations.

The computer algorithm is limited to only those elements where mine map data was available for the complete stratigraphic sequence. In those areas where only collateral information was available the quadrangle maps displayed in section 3.3.2 of this report were developed based on past mining history including recent strip mining activity through July 1974. The information relating to strip mining was extracted from remote sensing data by HRB-Singer in connection with other contract work.

3.3 CONCLUSIONS

3.3.1 General. Portions of twenty of the thirty-six U.S.G.S. 7 1/2 minute topographic quadrangle sheets defining this study are included

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in the subsidence potential computerized data base and have been classified by the SEAMS algorithm described in this report. The algorithm classifies subsidence potential on the basis of the support conditions in any seam in the stratigraphic sequence of a given forty acre elemental area. The total maximum subsidence at the surface is calculated to include all mined seams in the same stratigraphic sequence and forms the basis for assessing risk.

Along with the map products a significant contribution of this study is the computerized data base based on 25 critical parameters. This data base with continued updating can be the basis for future regional decision making in the Anthracite Region. It can be used to produce a multitude of map and statistical displays. Of particular importance is the seam correlation capability developed in the data base. With this capability regional products can be prepared.

The algorithm developed in this study is to be regarded as an interim product requiring further development. It represents the first attempt at the development of a meaningful predictive subsidence potential model. It is far from complete as the limitations discussed in Section 3.2 have shown. Nevertheless it presents a standarized technique for predicting subsidence potential based on the available mine extraction information. It gives insight, on a 40 acre site specific basis, to the subsurface characteristics of the anthracite coal fields. It represents a new contribution to the knowledge of subsidence prediction and should form the basis for further development both in the use of such predictive models in operational regional planning and in the specific correlation of subsidence occurrence to the conditions present in the Anthracite and Bituminous Mining Regions.

3.3.2 Subsidence Potential Classification Quadrangle Maps.

Thirty-six U.S.G.S. 7 1/2 minute quadrangles representing the map output of this study are depicted in reduced format in figures 22 to 57. These are the thirty-six quadrangles that define the Anthracite Region of Northeastern Pennsylvania. They are listed in the order of presentation in Table 16 and their distribution is shown in Figure 21.

The Quadrangles represent the base maps upon which have been superimposed the grid system adopted in this study. The Anthracite Region boundary, defined as the Mauch Chunk/ Pottsville contact, is drawn on the quadrangles and delineates the study area. The outcrop of the lowest mineable coal is shown by a dotted line and is derived from colliery maps. It usually depicts the lowest mineable coal in the Llewellyn formation. The colliery boundaries and names 9, 11, 12, 21 are imprinted on the quadrangles.

Superimposed upon the quadrangle grid system are the elemental area code numbers and letters that provide the subsidence potential classification and/or collateral information relating to mining (See Key, Table 17). In compiling these maps the computer generated class codes were incorporated. Collateral information was derived from the following sources:

(1) Mine maps not incorporated in mine map folios and where complete mine map information for all seams was unavailable.

(2) Second Pennsylvania topographic and geologic survey bulletins.

(3) U.S.G.S. geologic quadrangle map series. Coal investigation map series; and special investigation map series.

(4) Personal communications.

(5) Topographic quadrangle maps.

(6) Aerial photographs - July 1974.

(7) Geologic Map of Pennsylvania.

The maps provide varying levels of information. The Subsidence Potential Class Codes (1, 2, or 3) represent the most reliable data as they are derived from mine maps. Stripped areas (T) are derived from three sources; mine maps, topographic maps, and aerial photography and are relatively complete. They indicate surface stripping but do not provide information on depth of stripping or whether previous deep mining occurred. No mining (N) is indicative of undisturbed areas. It characterizes unmined areas and is less reliable information than stripped areas. The information is derived from mine maps and geologic maps. Since no mine maps or geologic maps were available for the Eastern Middle Field the only no mining information available came from colliery maps of the field. Deep Mining (M) information is derived from mine maps, geologic maps, and topographic maps. Although the Eastern Middle Field has been extensively deep mined this information is only displayed on those elements where a mine entry or roof collapse is indicated on the topographic maps. The user is cautioned that although the majority of elements in the Eastern Middle Field carry only a stripped (T) designation it is more than likely the element has been deep mined. In extensive strip mining operations in this field operators have seldom encountered unmined coal. In those cases where knowledge of deep mining is known and the surface has been stripped an MT designation is given. In those areas where a flushing project has been completed an F designation is added to the element.

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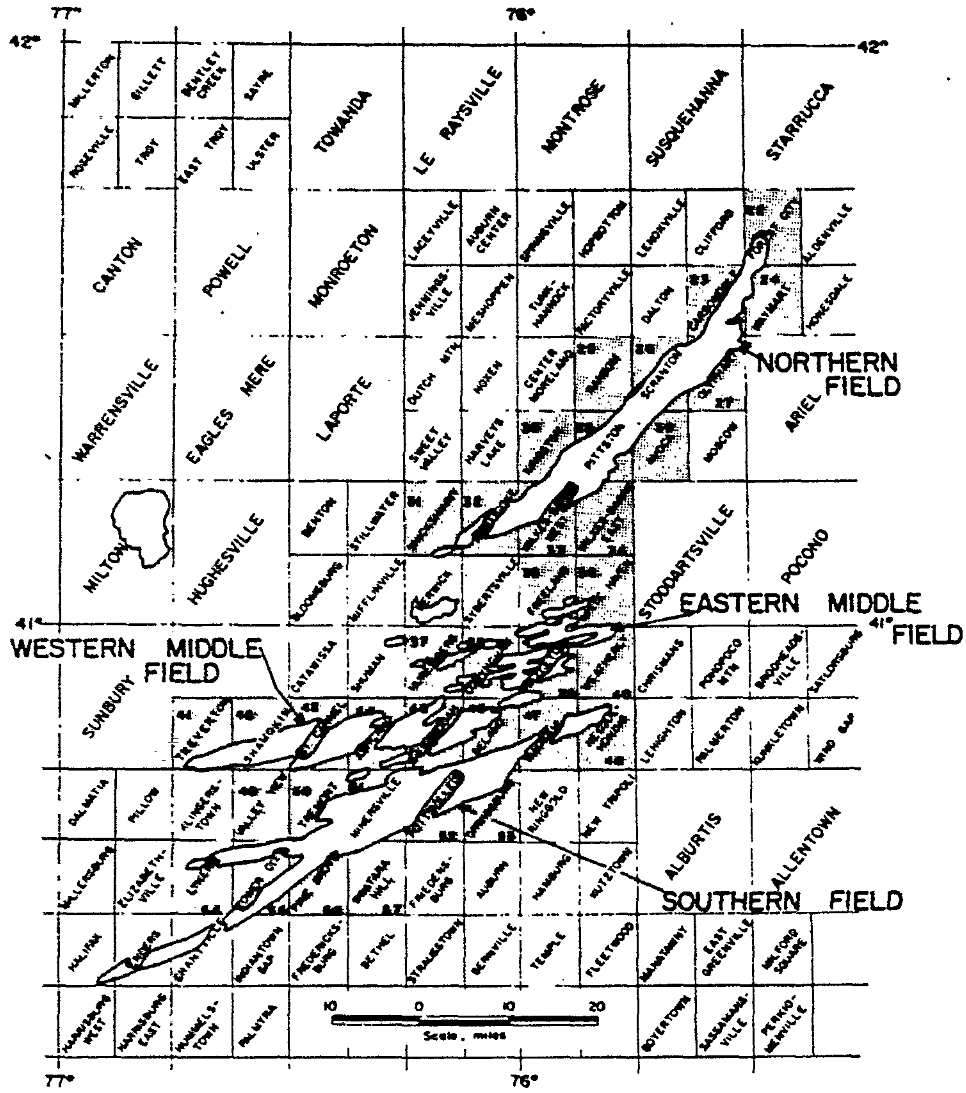

FIG. 21 INDEX MAP SHOWING DISTRIBUTION OF FIGURES 22-57

75-13

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TABLE 16 SUBSIDENCE POTENTIAL CLASSIFICATION QUADRANGLE MAPS

74-144

FIGURE #	QUADRANGLE	U.S. GEOLOGICAL SURVEY GEOLOGICAL MAP REFERENCE
22	FOREST CITY	
23	CARBONDALE	
24	WAYMART	
25	RANSOM	
26	SCRANTON	
27	OLYPHANT	
28	KINGSTON	
29	PITTSTON	
30	AVOCA	
31	SHICKSHINNY	
32	NANTICOKE	
33	WILKES BARRE WEST	
34	WILKES BARRE EAST	I-753
35	FREELAND	
36	WHITE HAVEN	
37	NURENBERG.	
38	CONYNGHAM	
39	HAZLETON	
40	WEATHERLY	
41	TREVERTON	C-48, I-734
42	SHAMOKIN	C-46, C-47, I-734
43	MOUNT CARMEL	C-3, C-7, C-10, C-12, GQ-919
44	ASHLAND	C-13, C-14, GQ-918
45	SHENANDOAH	C-19, C-21, GQ-761
46	DELANO	C-25, GQ-1054, I-737
47	TAMAQUA	I-899
48	NESQUEHONING	
49	VALLEY VIEW	I-529, GQ-699
50	TREMONT	C-43, GQ-692, I-528
51	MINERSVILLE	C-43, GQ-690, I-528
52	POTTSVILLE	I-681, GQ-1028
53	ORWIGSBURG	I-689, GQ-1029
54	LYKENS	GQ-701, I-529
55	TOWER CITY	GQ-698, I-529
56	PINE GROVE	GQ-691, I-528
57	SWATARA HILL	GQ-689, I-528

THIS TABLE LISTS THE QUADRANGLE MAPS IN THE ORDER OF PRESENTATION.

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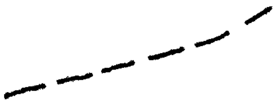
TABLE 17 KEY TO SUBSIDENCE POTENTIAL CLASSIFICATION QUADRANGLE MAPS

74-144

	BOUNDARY OF ANTHRACITE REGION: DEFINED AS MAUCH CHUNK/POTTSVILLE CONTACT. ARROW POINTS TO PENNSYLVANIAN ROCKS. NOT USED IN NORTHERN FIELD.
	LOWEST MINEABLE COAL AS DEPICTED ON COLLIERY MAPS: INCLUDES MOSTLY LLEWELLYN ROCKS.
	COLLIERY

ELEMENTAL AREA CODE	
1	PRECAUTIONARY AREA . FUTURE SUBSIDENCE PROBABLE IF SUBSIDENCE HAS NOT ALREADY PROGRESSED TO COMPLETION. (SITE ENGINEERING RECOMMENDED)
2	SUBSIDENCE POSSIBLE: S_{MAX} 0.0<0.5 (SITE ENGINEERING RECOMMENDED)
3	NO SUBSIDENCE: $S_{MAX} = 0.0$
T	STRIPPED - NO INFORMATION ON DEEP MINING
N	NO MINING
M	DEEP MINED
MR	DEEP MINED AND ROBBED
MT	DEEP MINED AND SURFACE STRIPPED
F	FLUSHED

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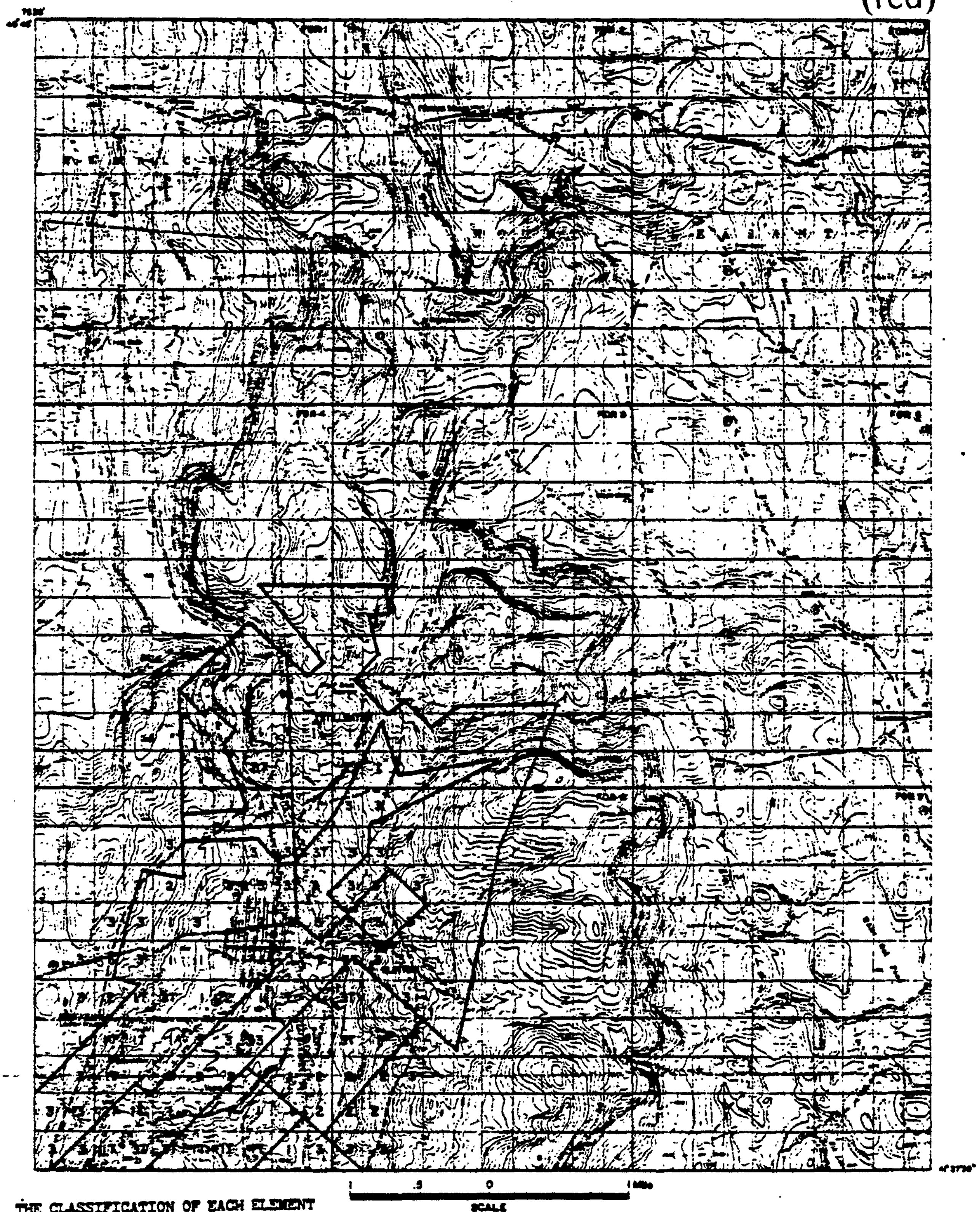

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 22 FOREST CITY QUADRANGLE

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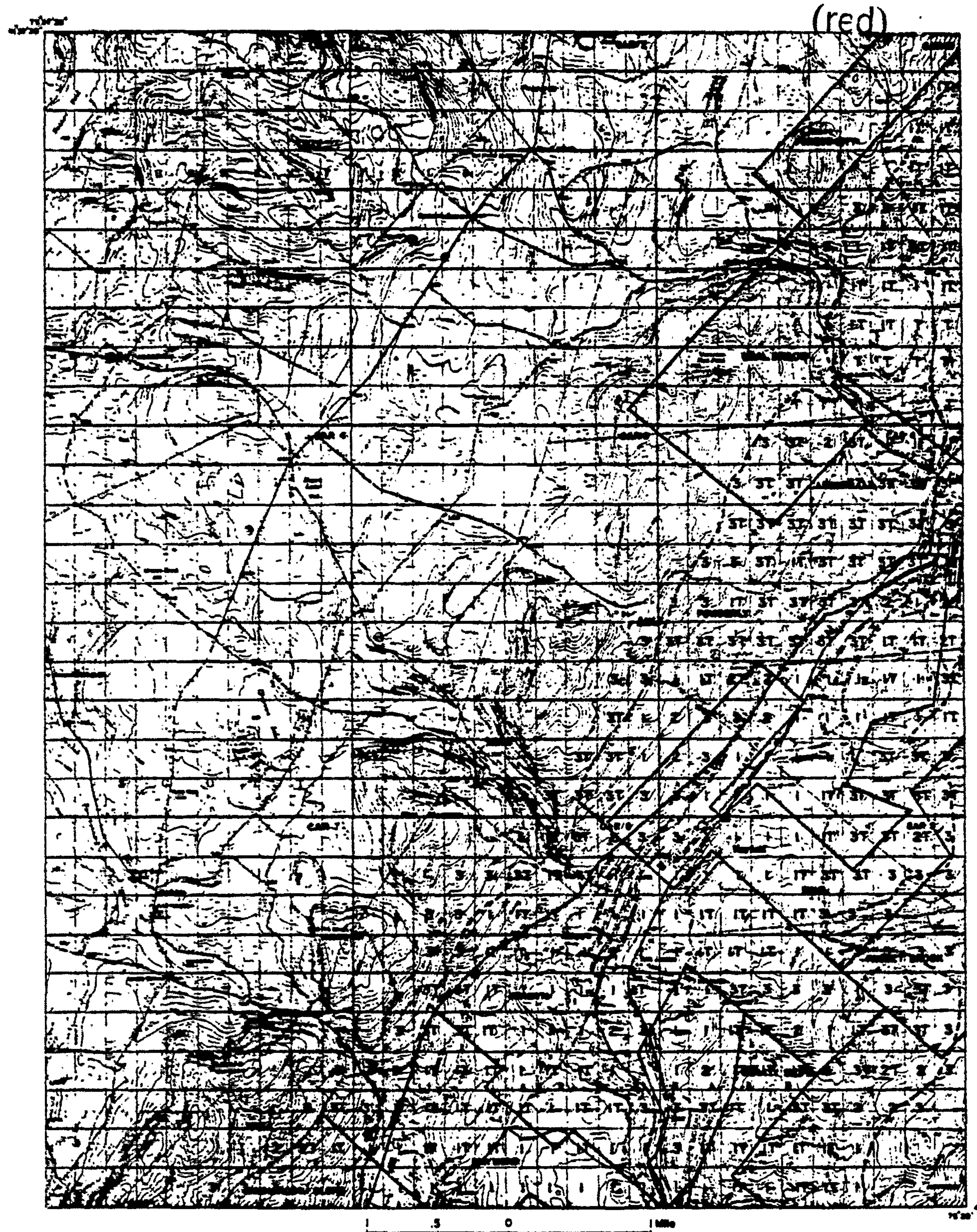

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 23 CARBONDALE QUADRANGLE

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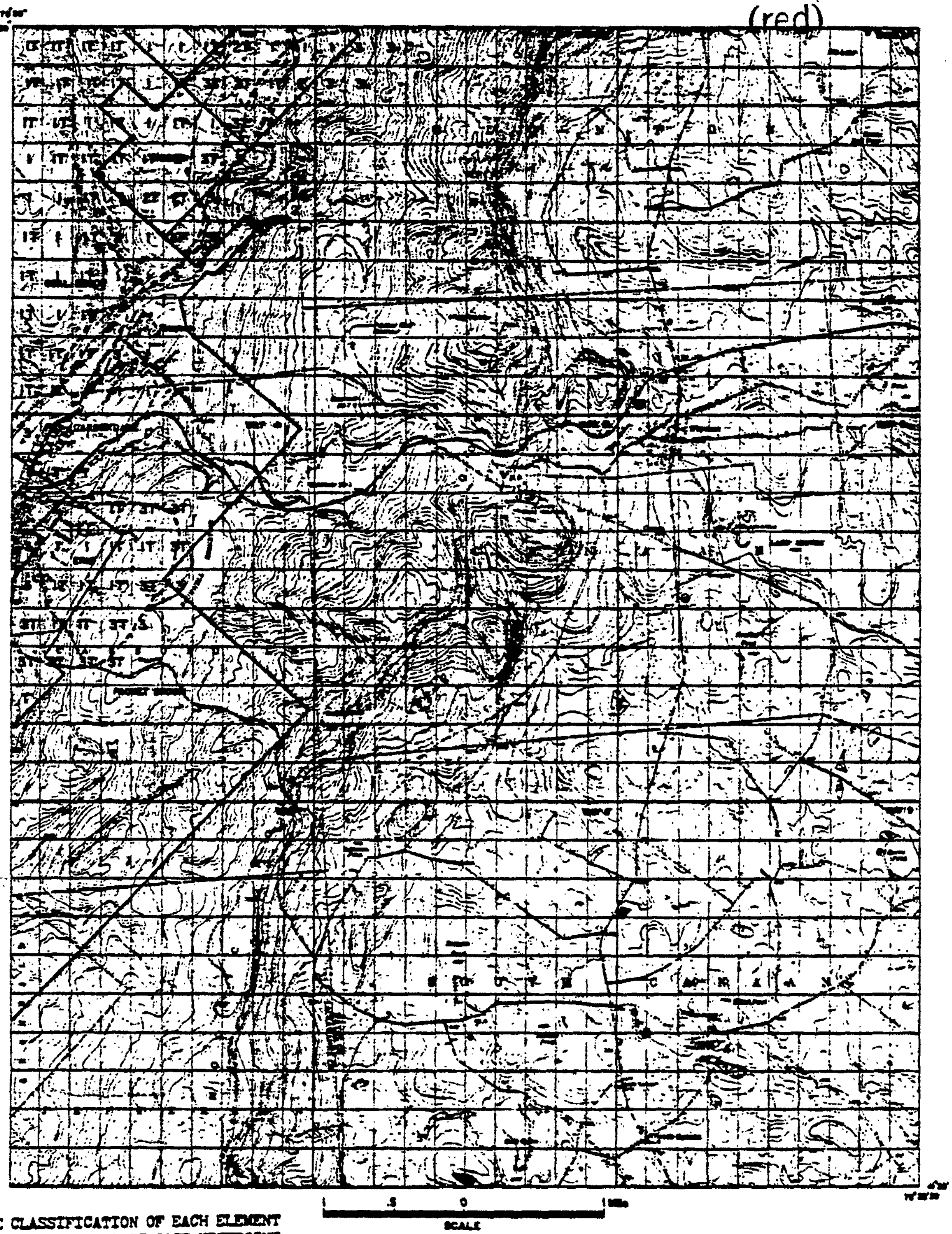

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 24 WAYMART QUADRANGLE

76-144

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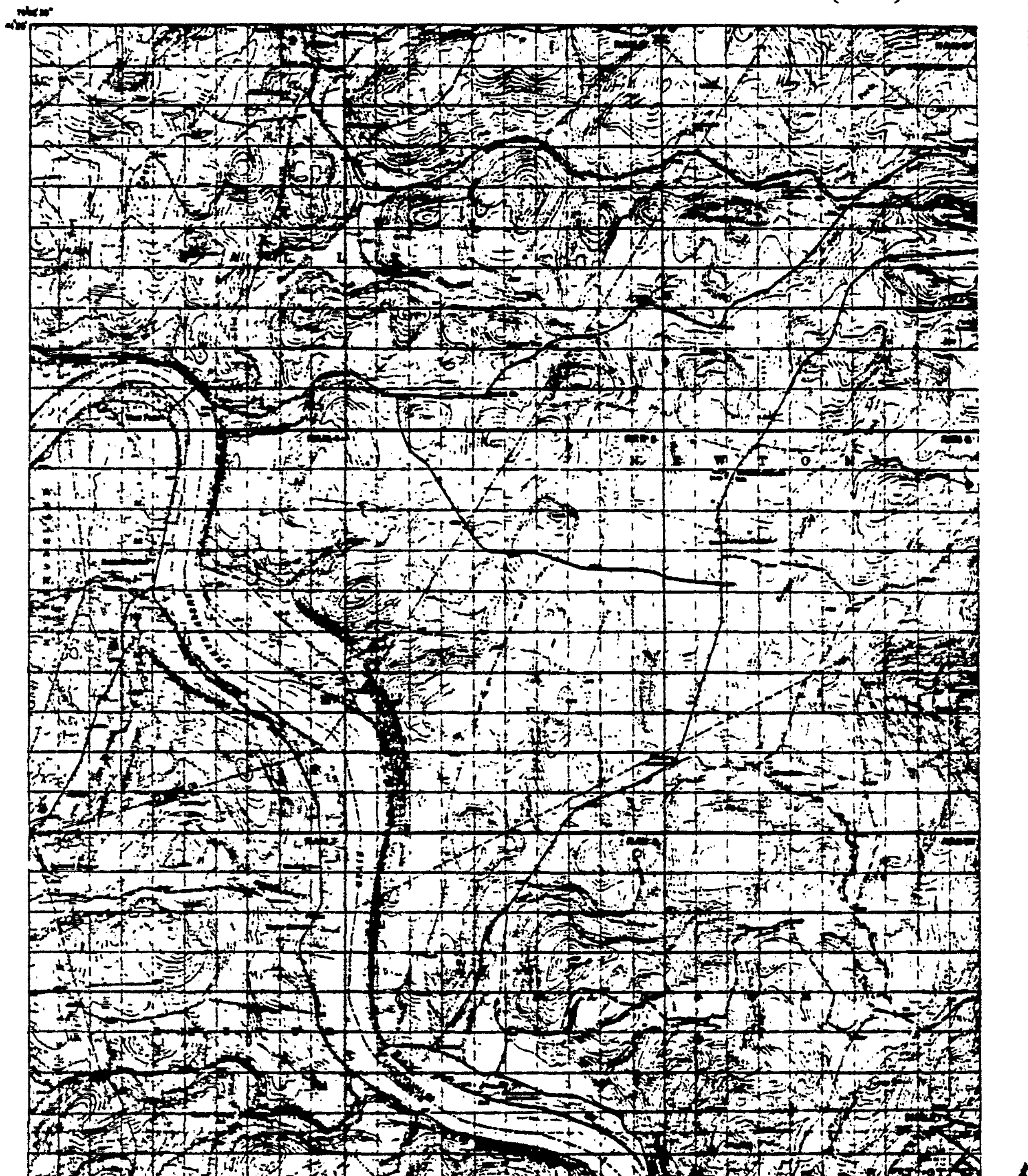

1 .5 0 1 Mile
SCALE

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 25 RANSOM QUADRANGLE

site

sce #2

74-164

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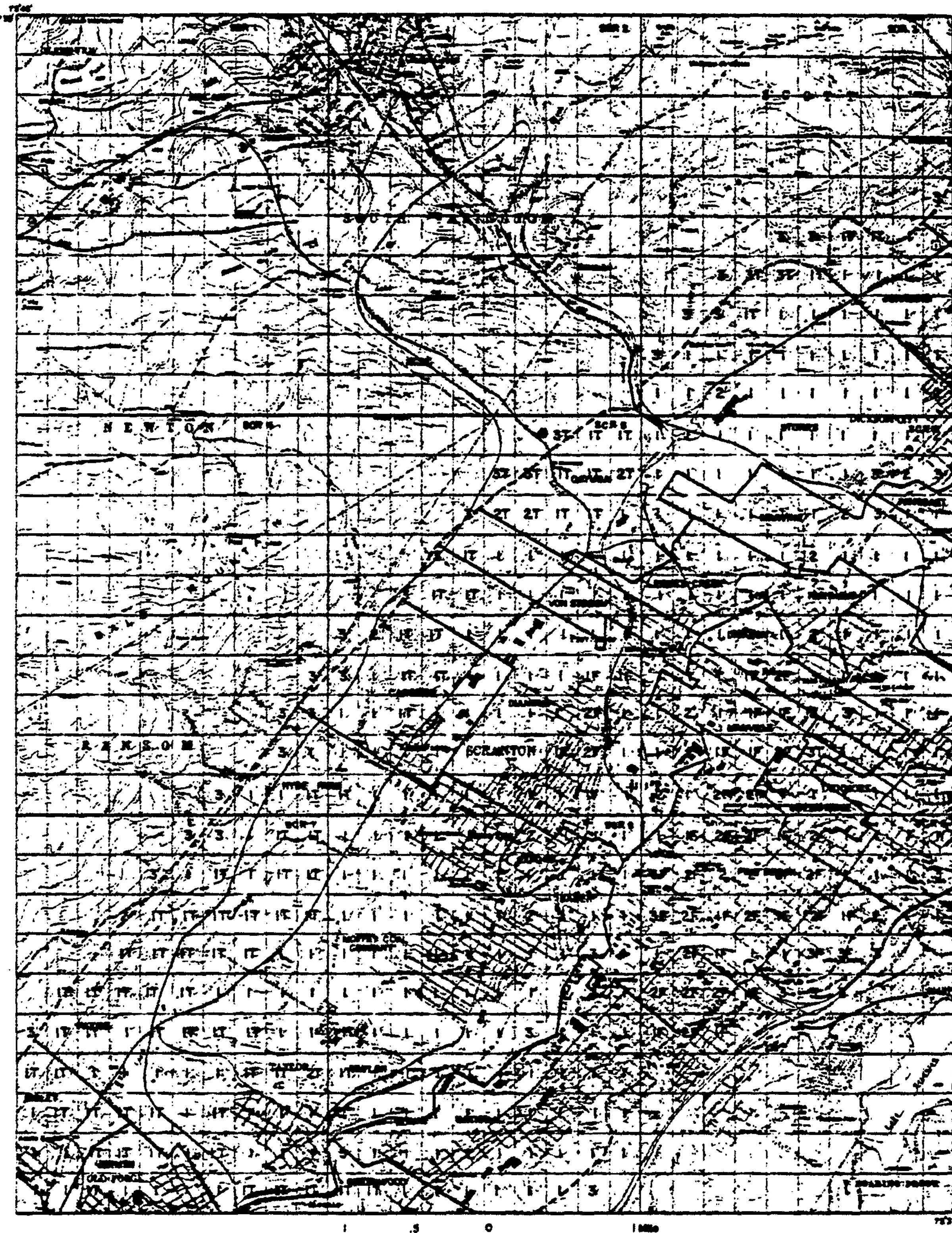

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 26 SCRANTON QUADRANGLE

76-144

AR100128

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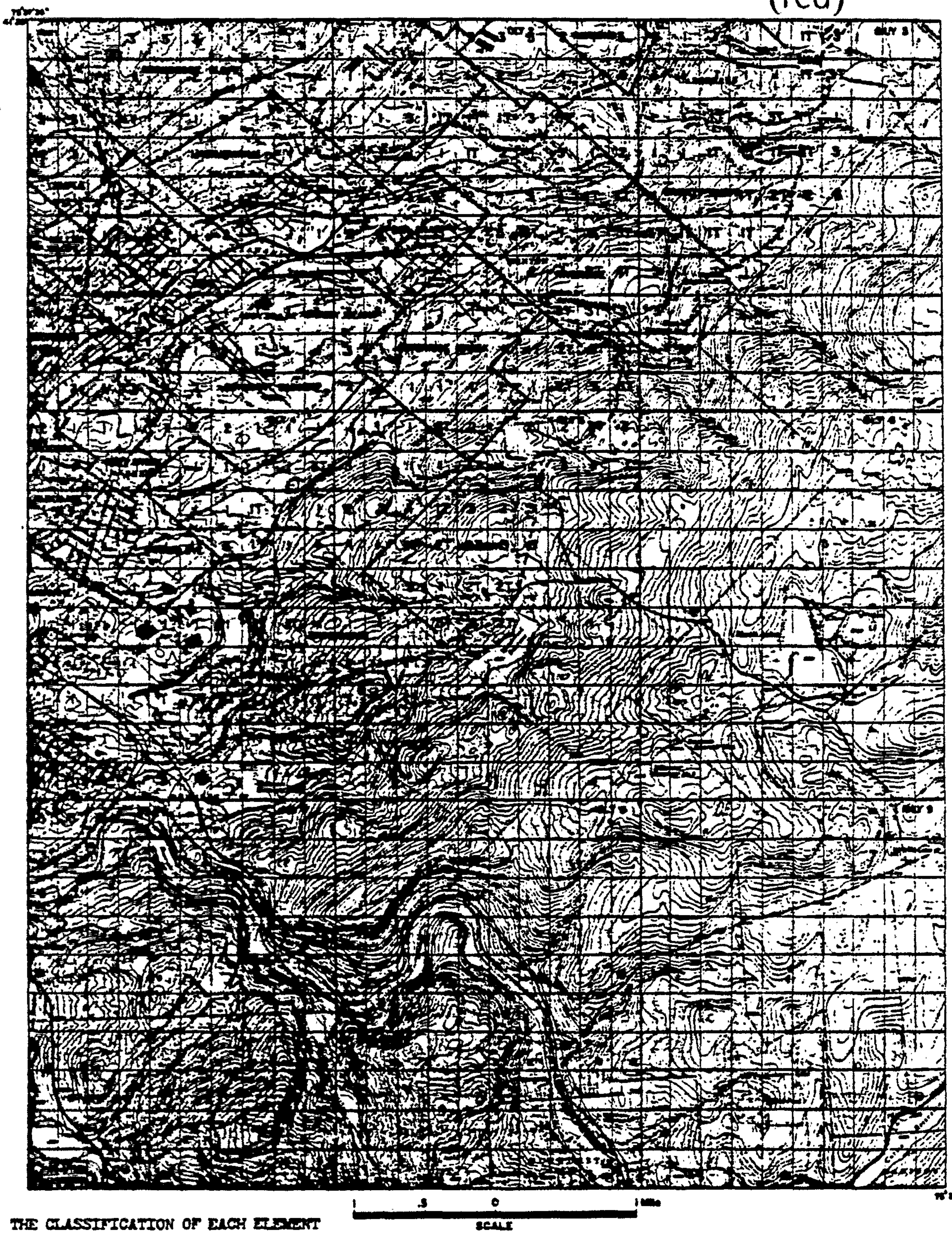
(red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 27 OLYPHANT QUADRANGLE

74-144

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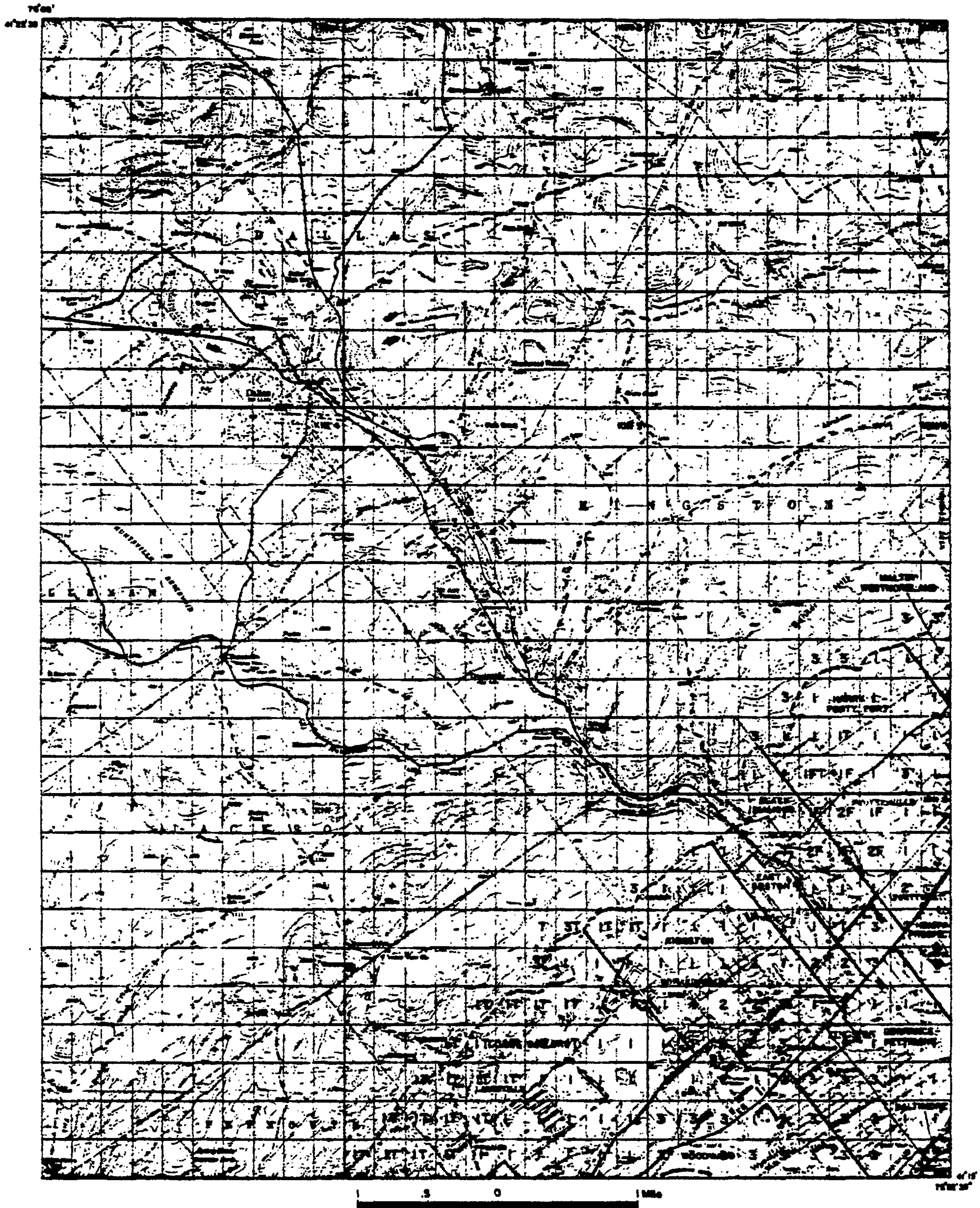

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 28 KINGSTON QUADRANGLE

AR100130

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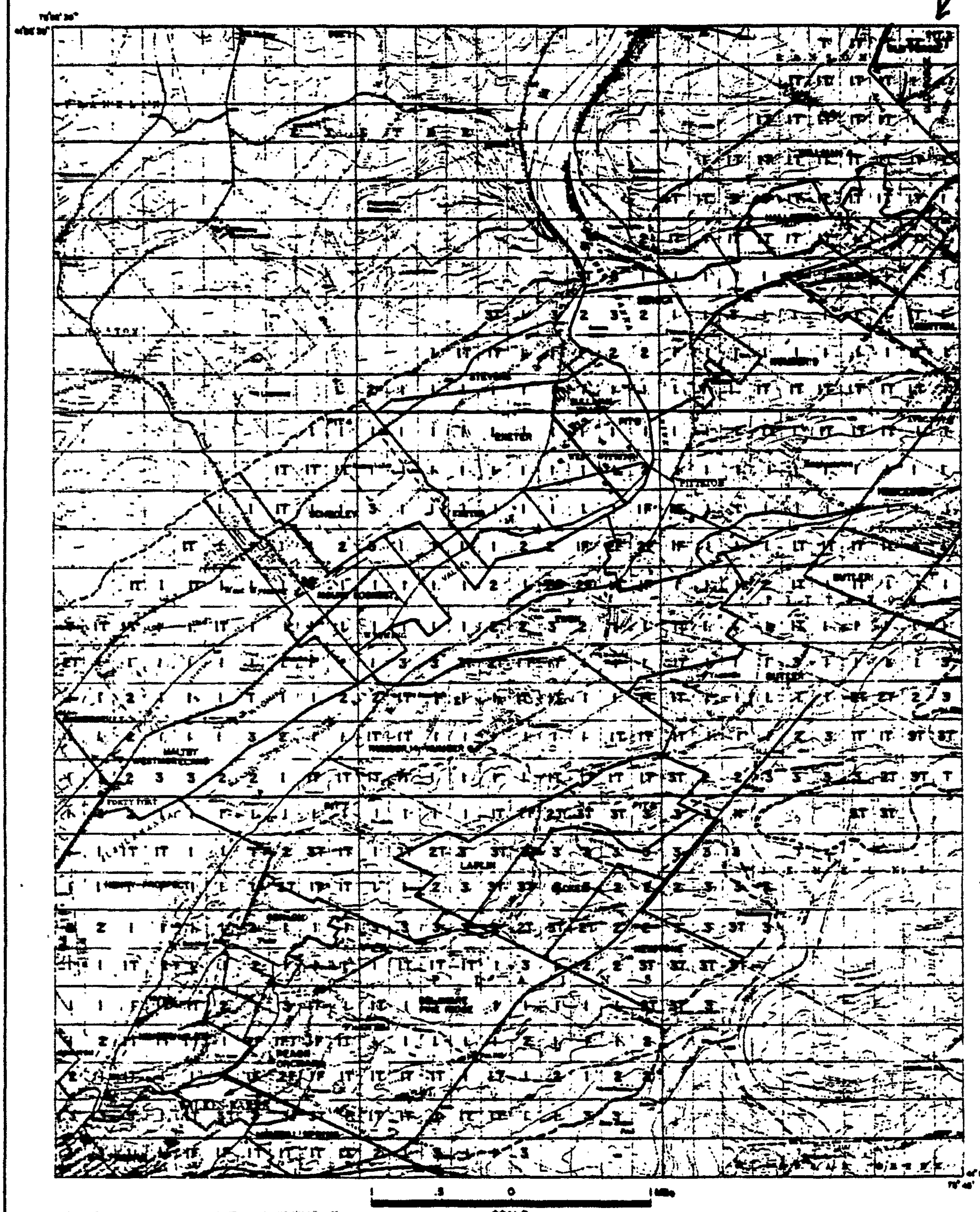
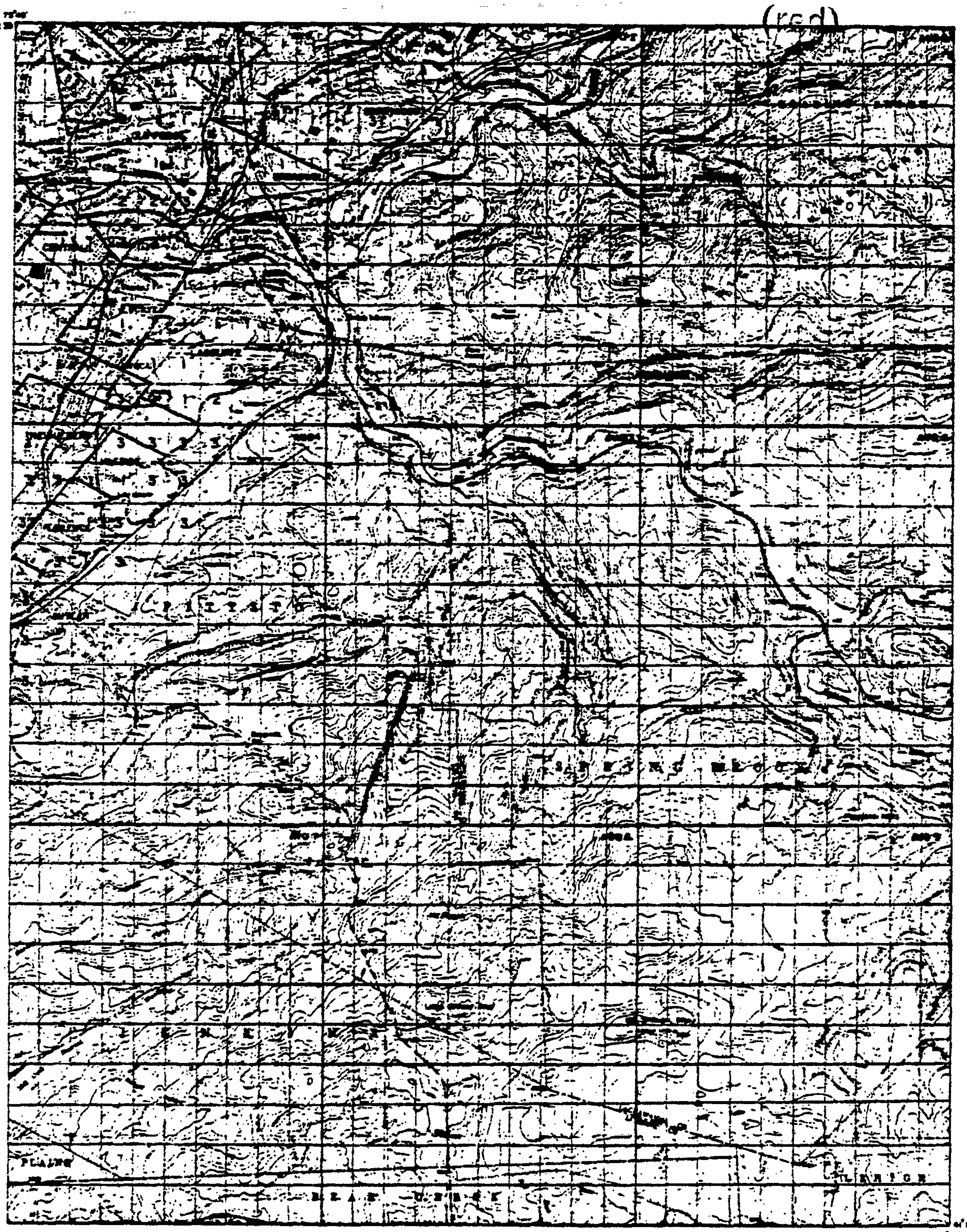


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 29 PITTSTON QUADRANGLE

ORIGINAL (red)



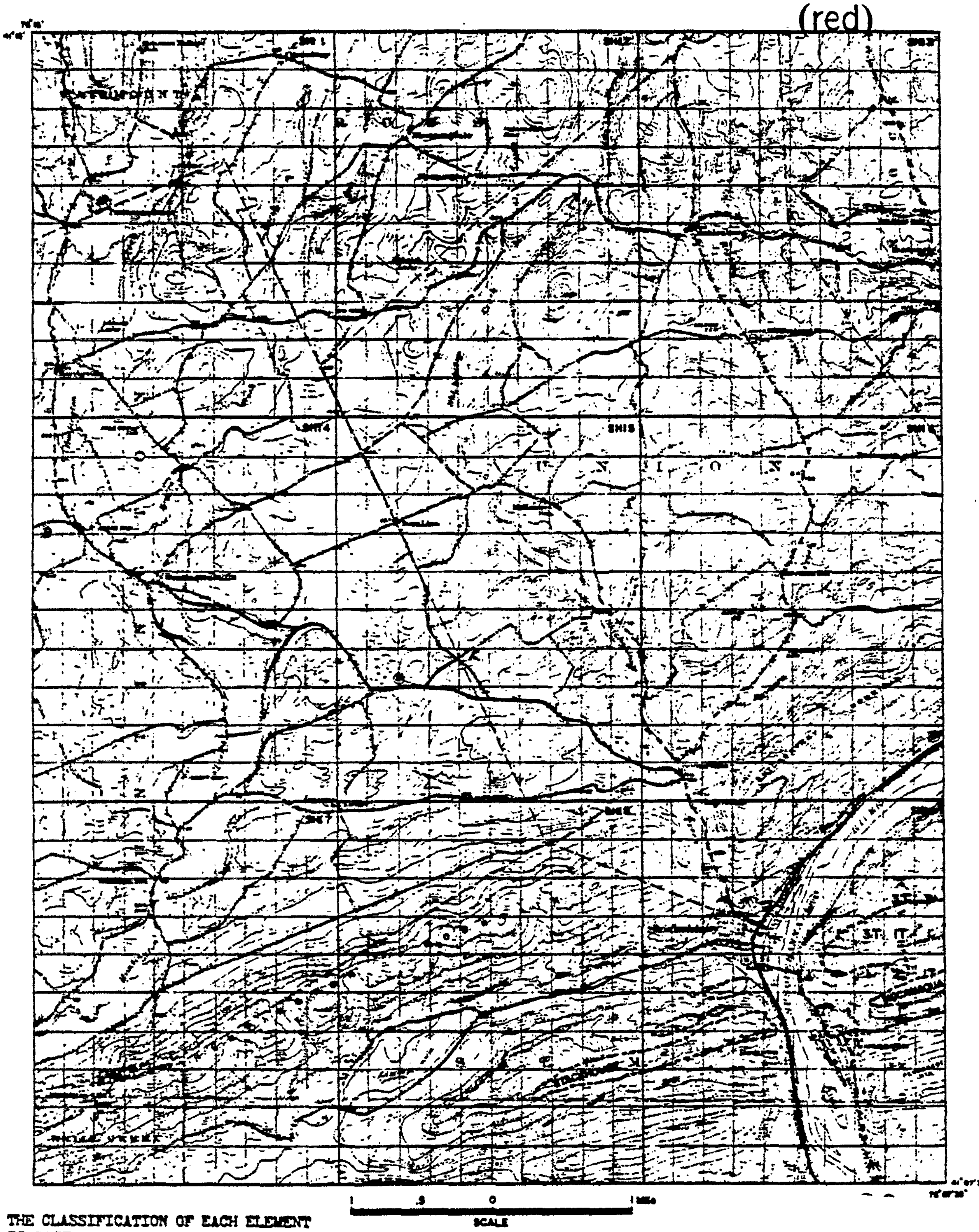
1 .5 0 1 Mile
SCALE

THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

FIGURE 30 AVOCA QUADRANGLE

76-144

ORIGINAL
(red)



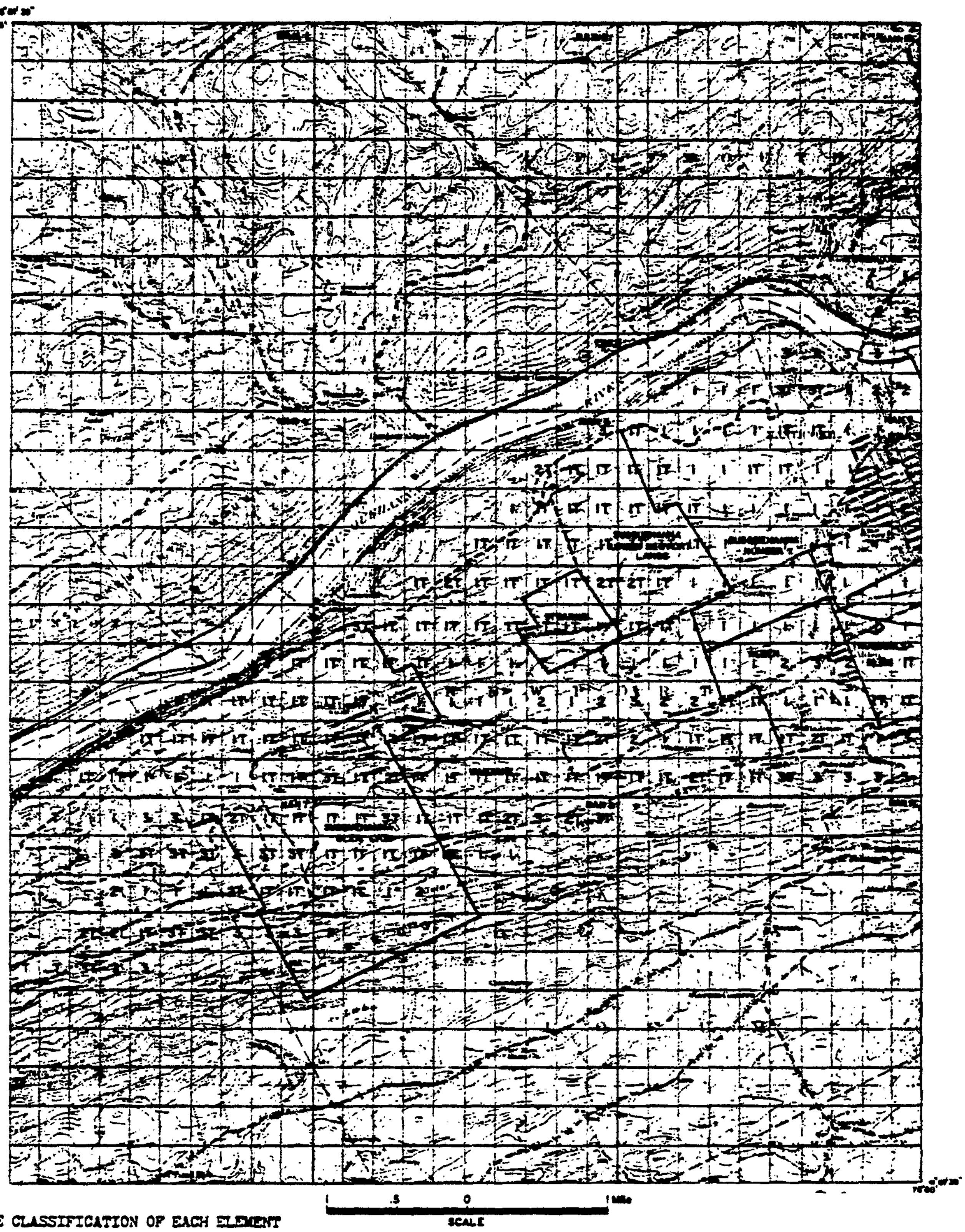
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

SCALE

FIGURE 31 SHICKSHINNY QUADRANGLE

ORIGINAL

(red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

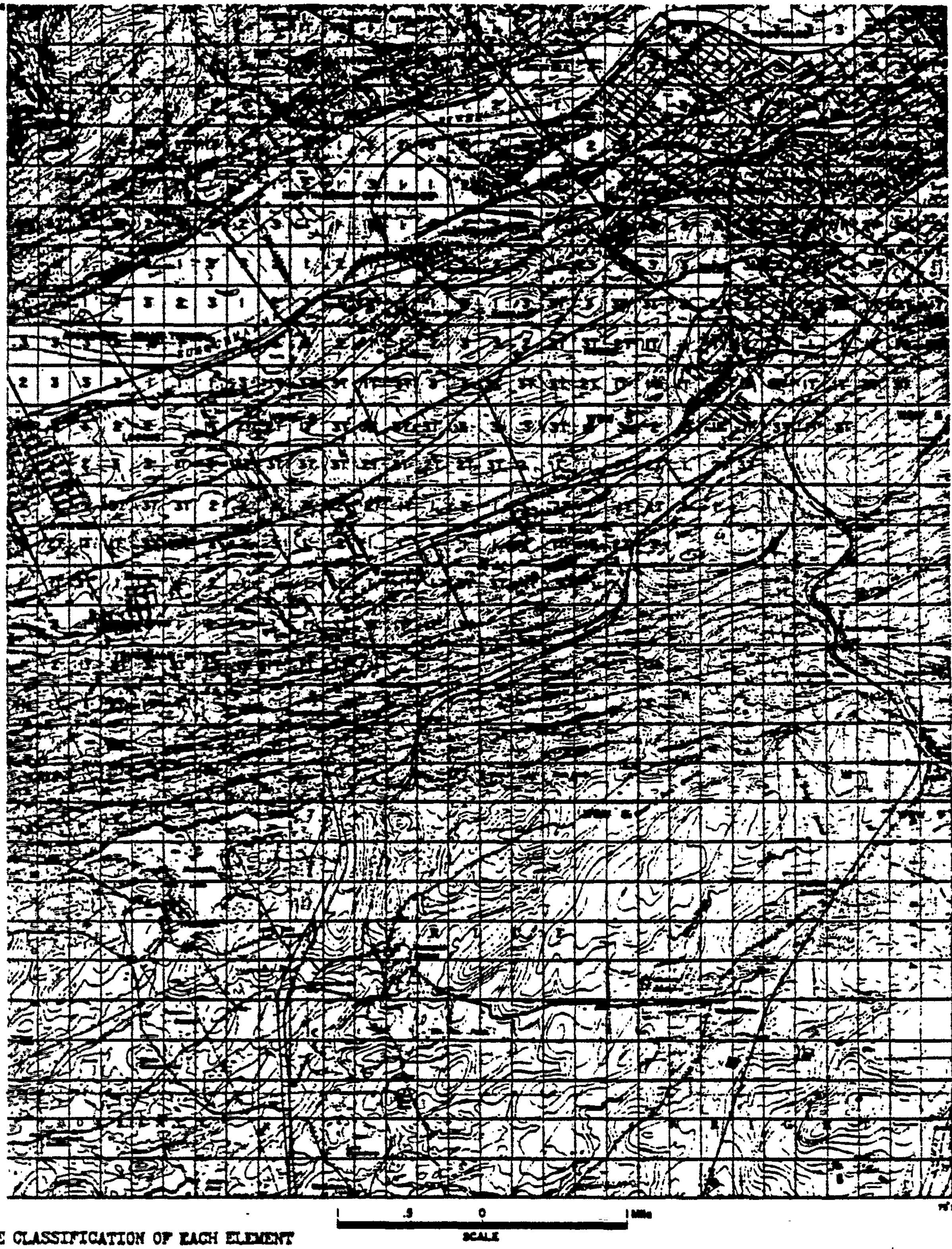
FIGURE 32 NANTICOKE QUADRANGLE

74-144

AR100134

ORIGINAL

(red)

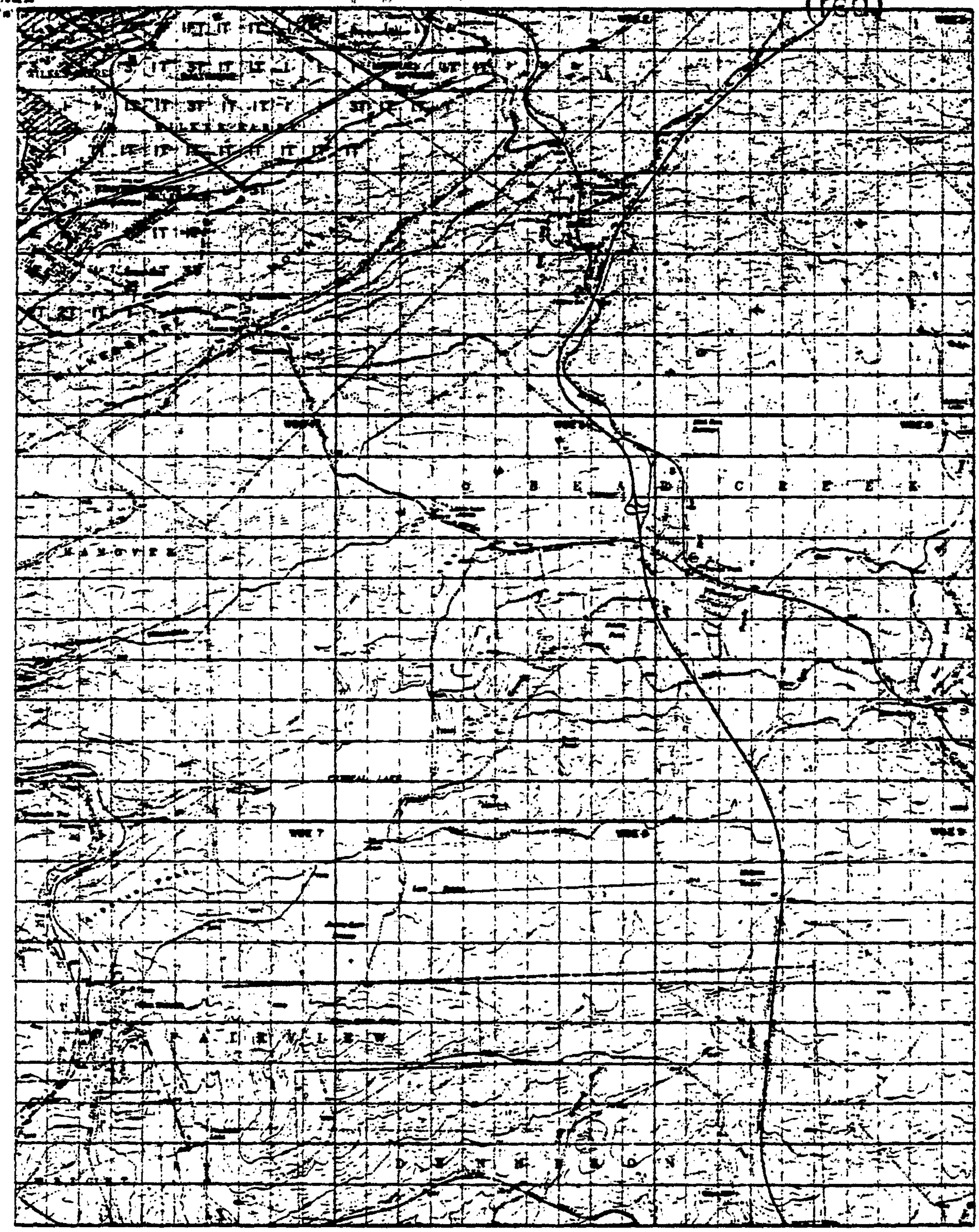


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 33 WILKES-BARRE WEST QUADRANGLE

AR100135

ORIGINAL
(red)



1 .5 0 1 Mile
SCALE

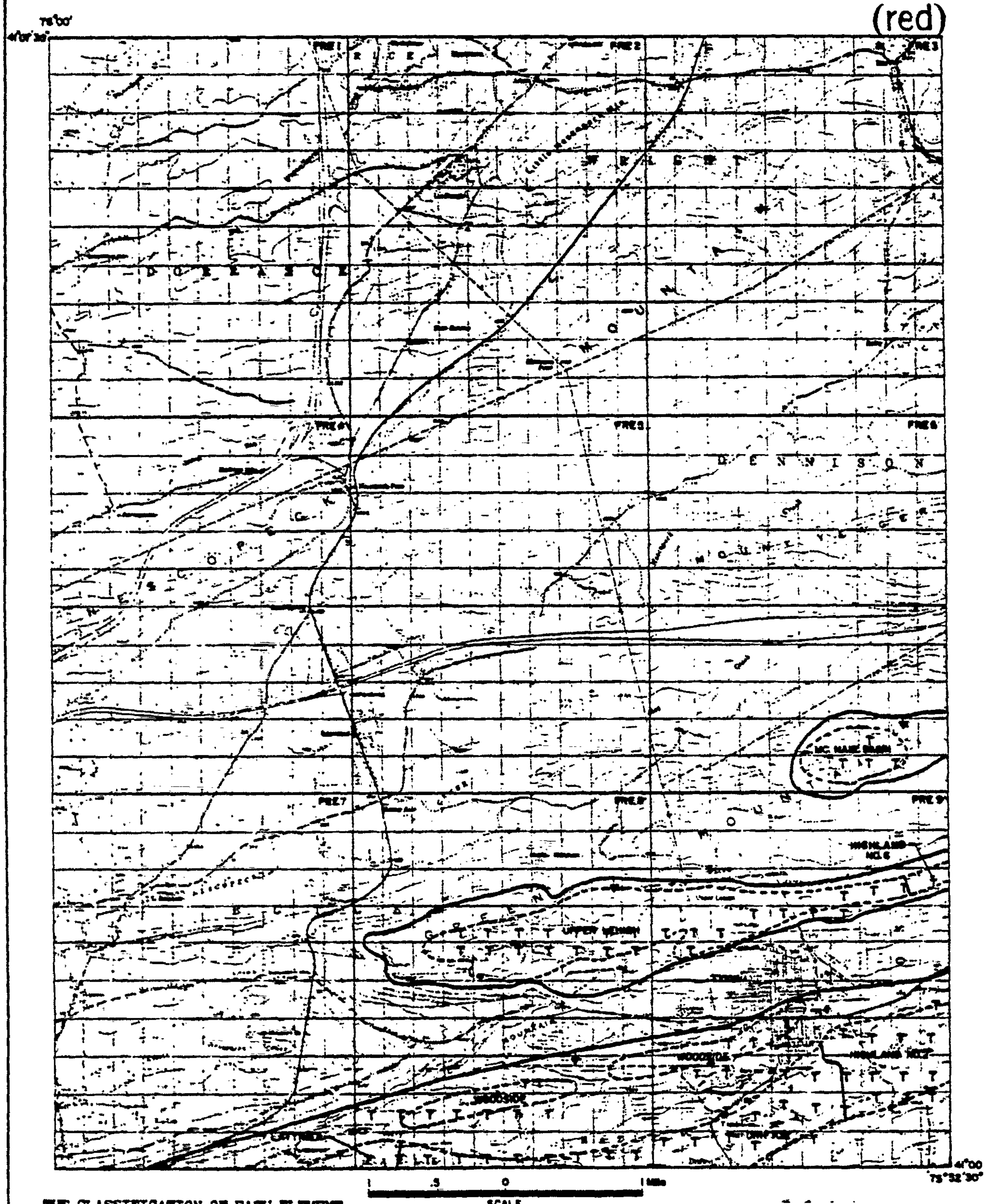
REF: U.S.G.S. 1-753

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 34 WILKES-BARRE EAST QUADRANGLE

AR100136

ORIGINAL
(red)



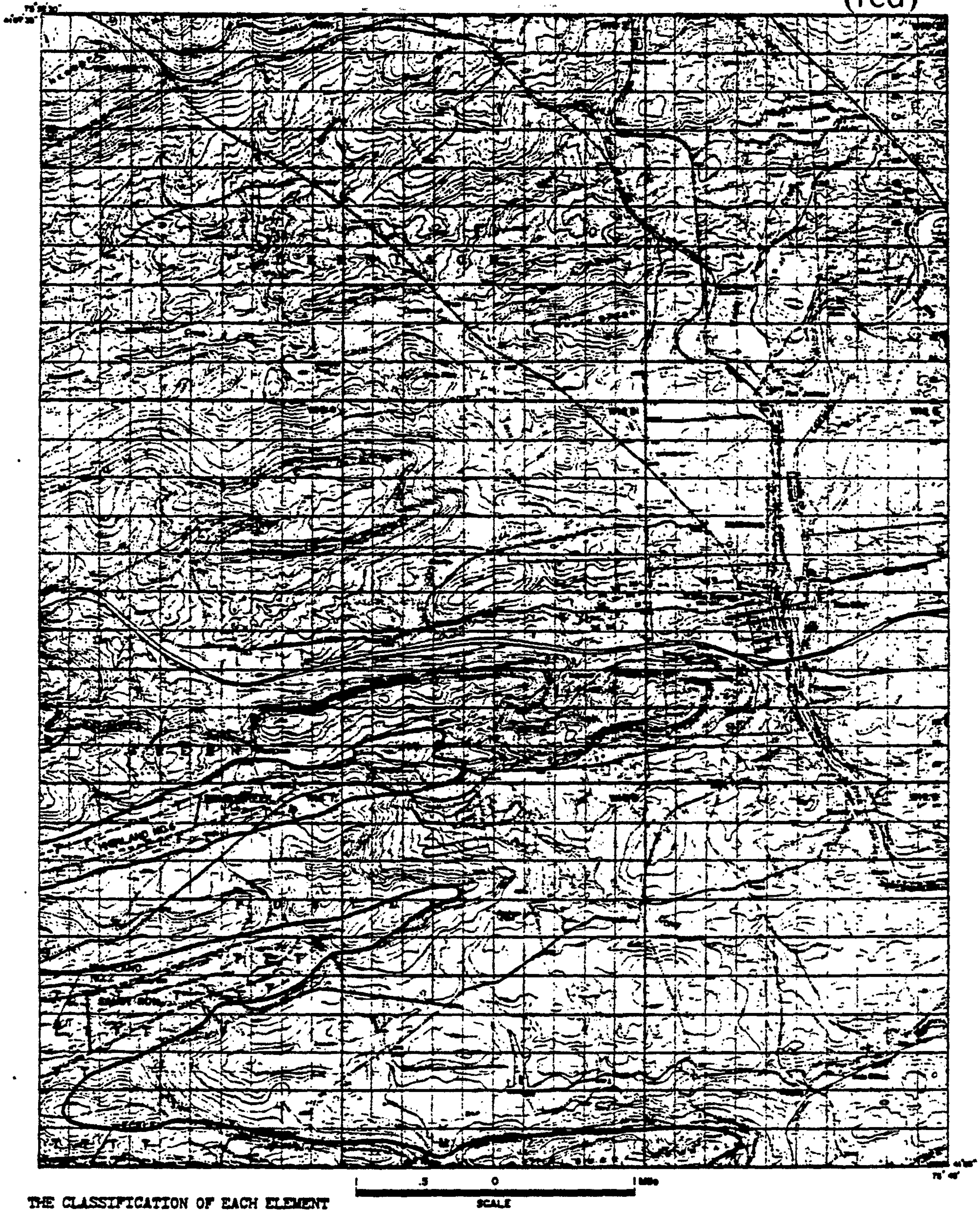
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 35 FREELAND QUADRANGLE

AR100137

ORIGINAL

(red)

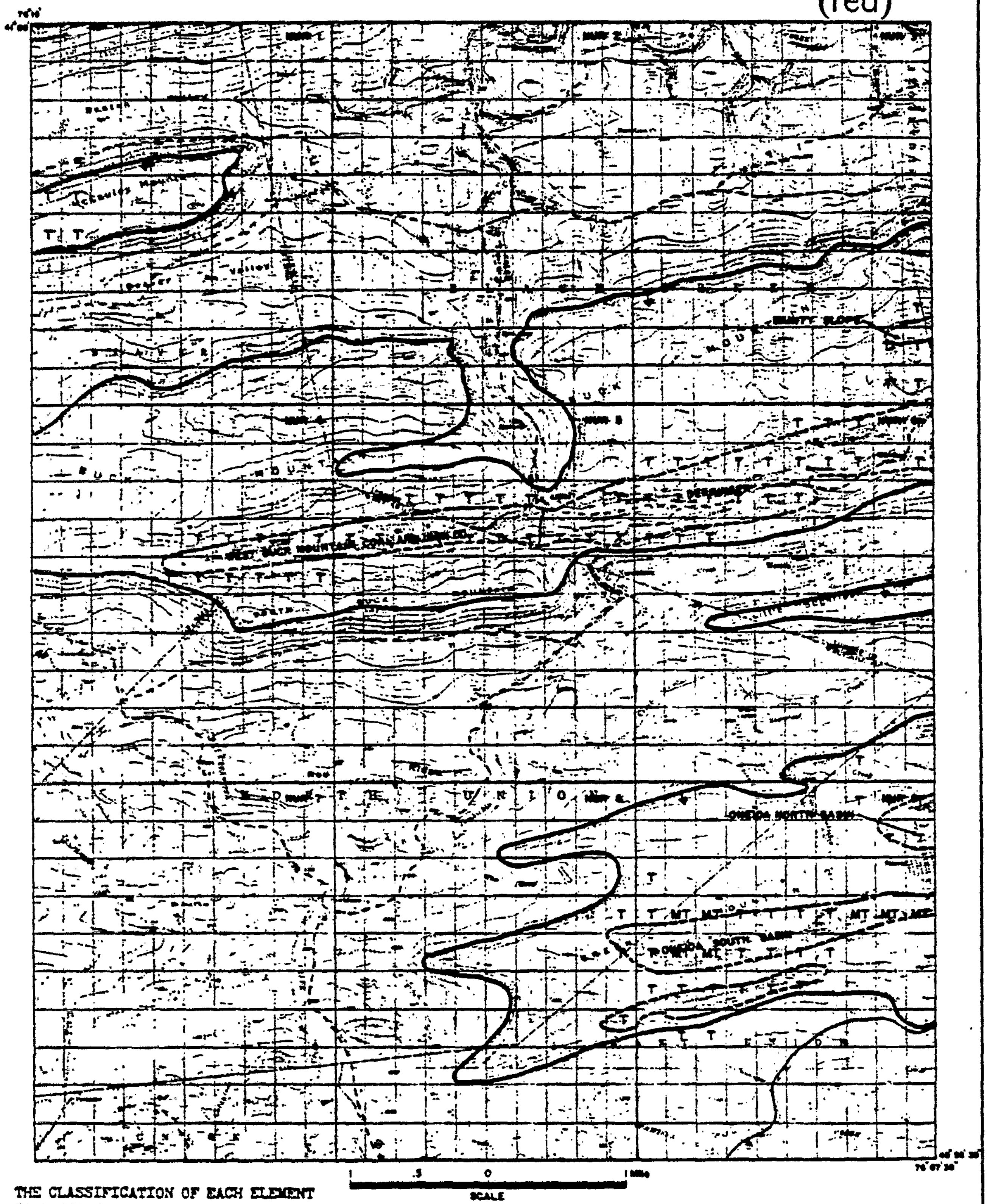


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 36 WHITE HAVEN QUADRANGLE

ORIGINAL

(red)



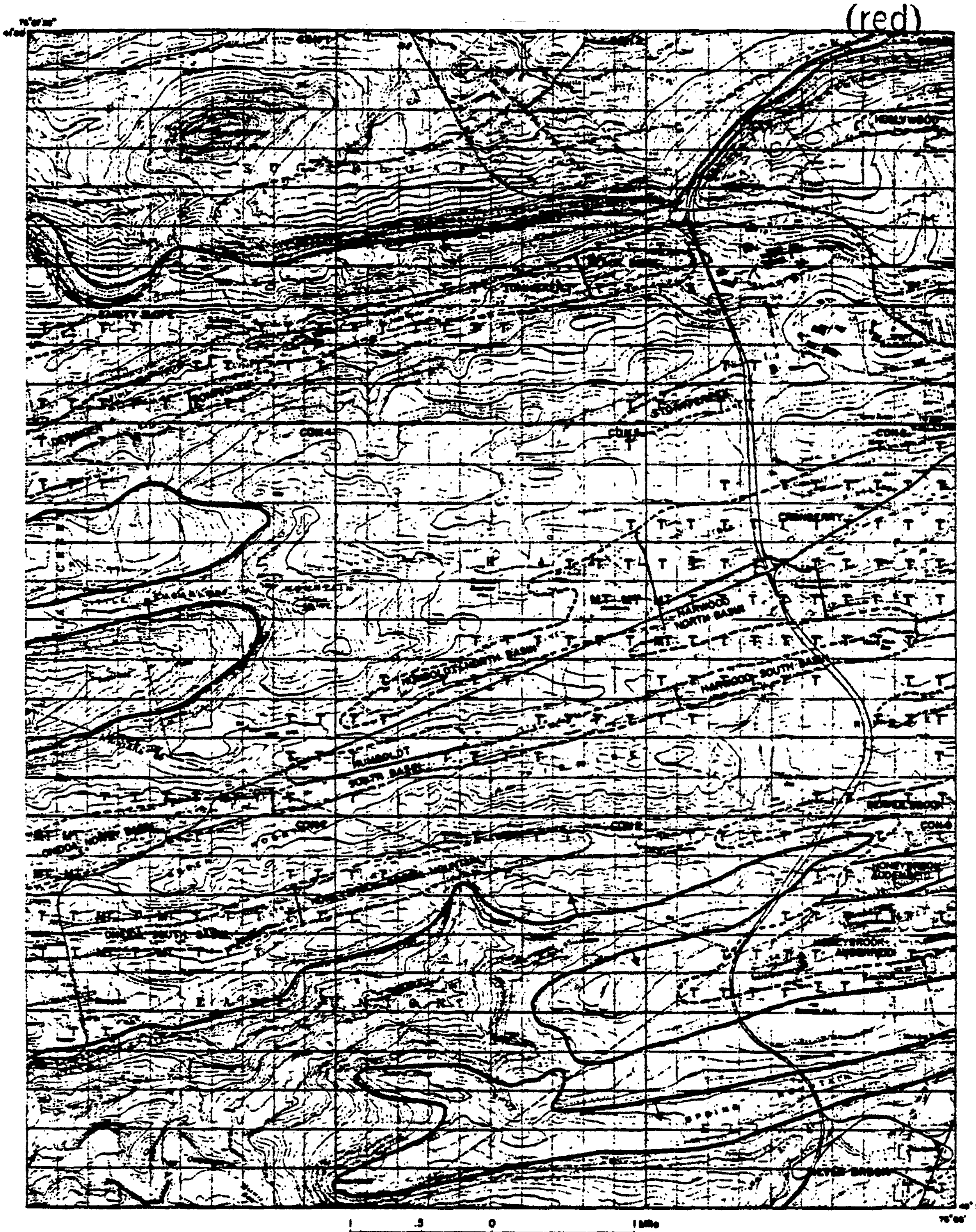
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 37 NUREMBERG QUADRANGLE

76-144

ORIGINAL

(red)



THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

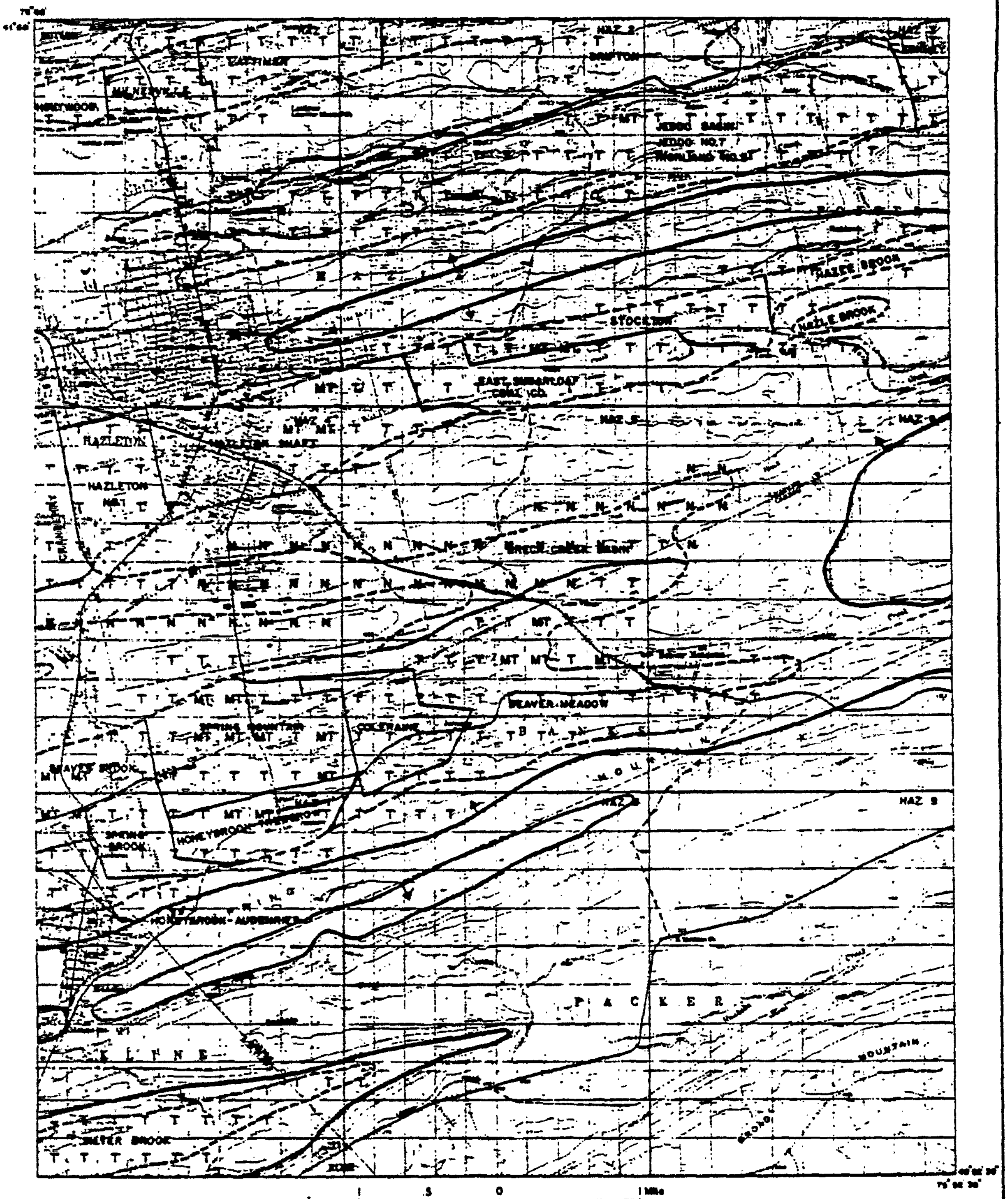
FIGURE 38 CONYNGHAM QUADRANGLE

76-144

AR100140

ORIGINAL

(red)

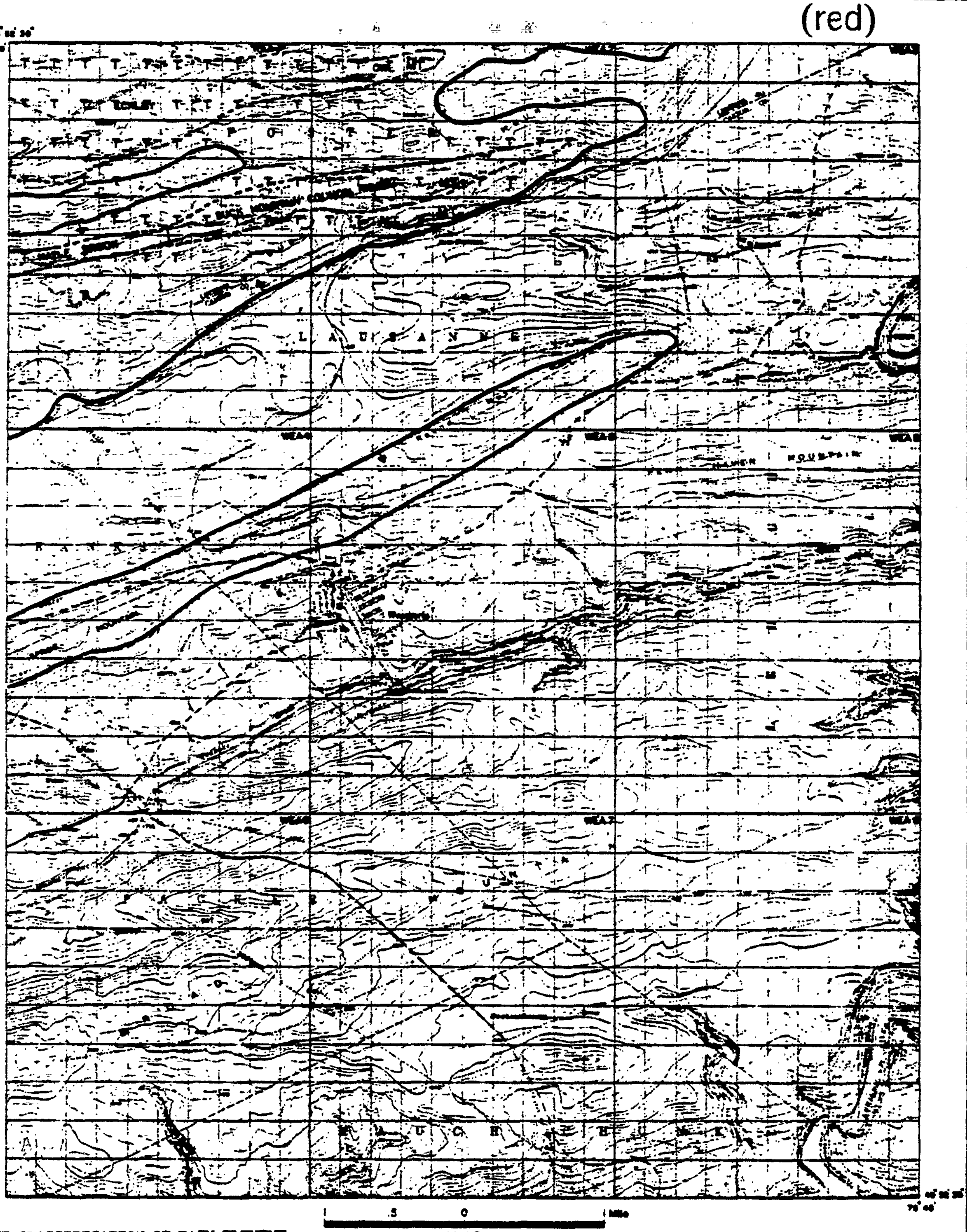


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 39 HAZLETON QUADRANGLE

AR100141

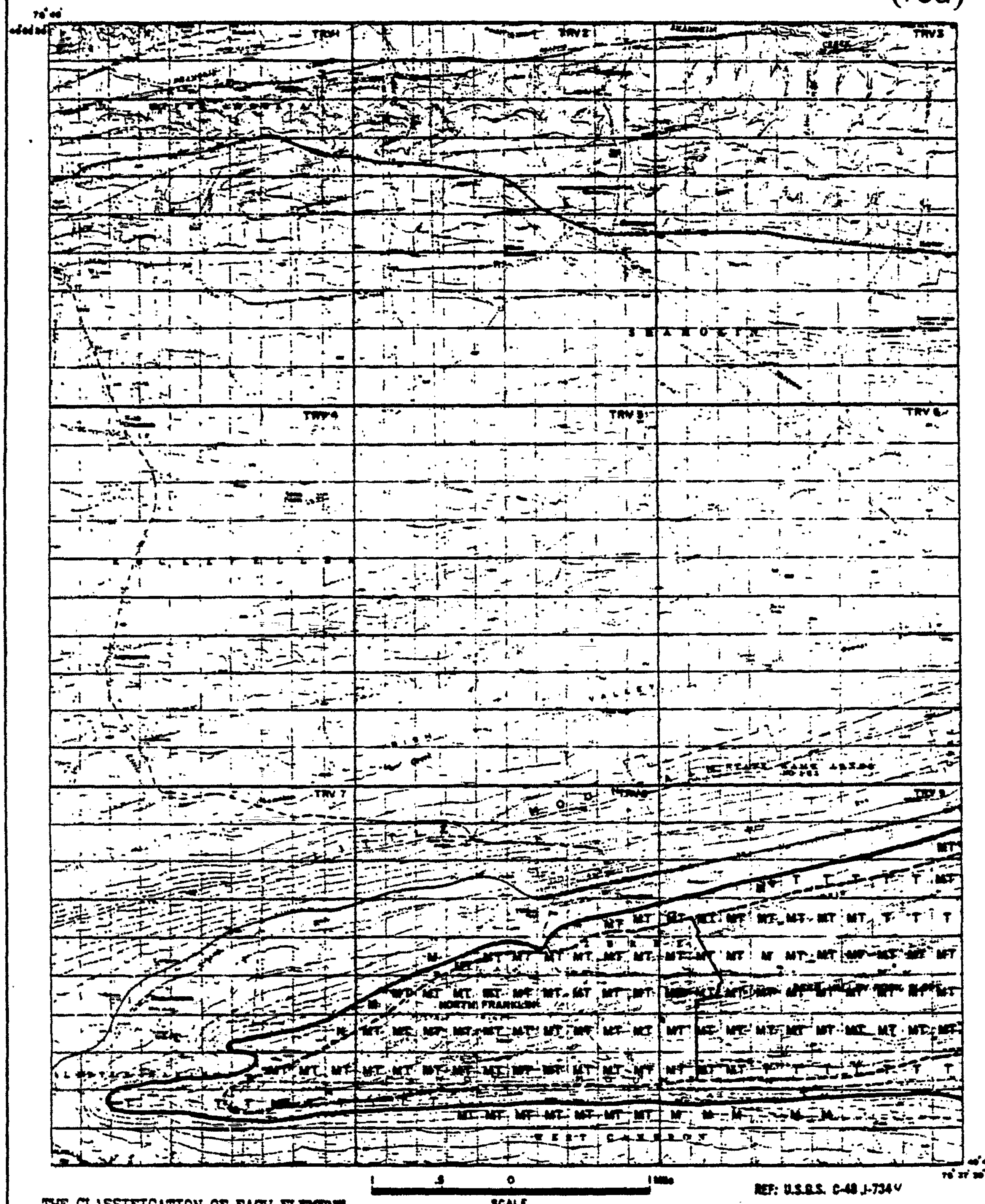
ORIGINAL
(red)



THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

FIGURE 40 WEATHERLY QUADRANGLE

76-144

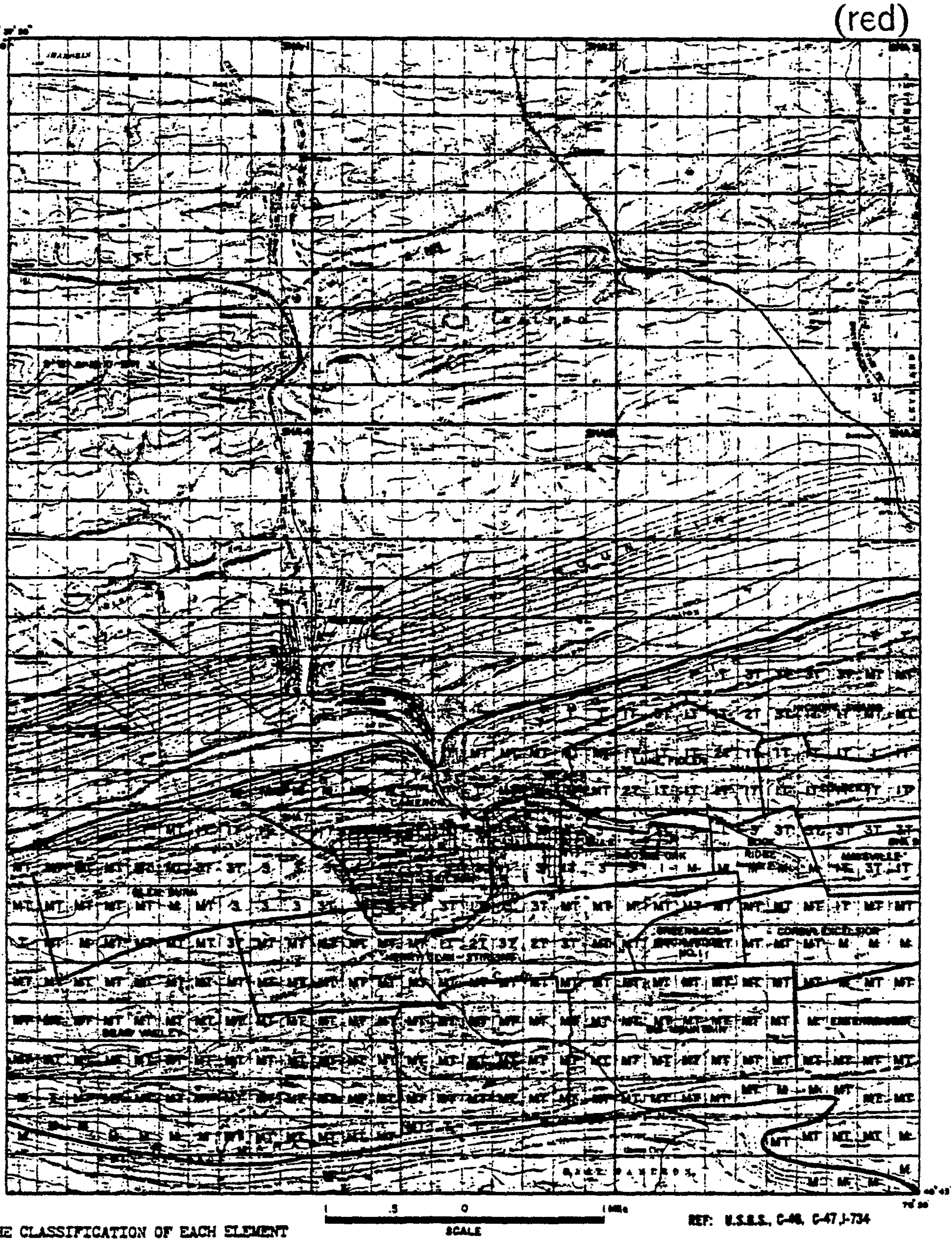


THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

FIGURE 41 TREVORTON QUADRANGLE

ORIGINAL

(red)



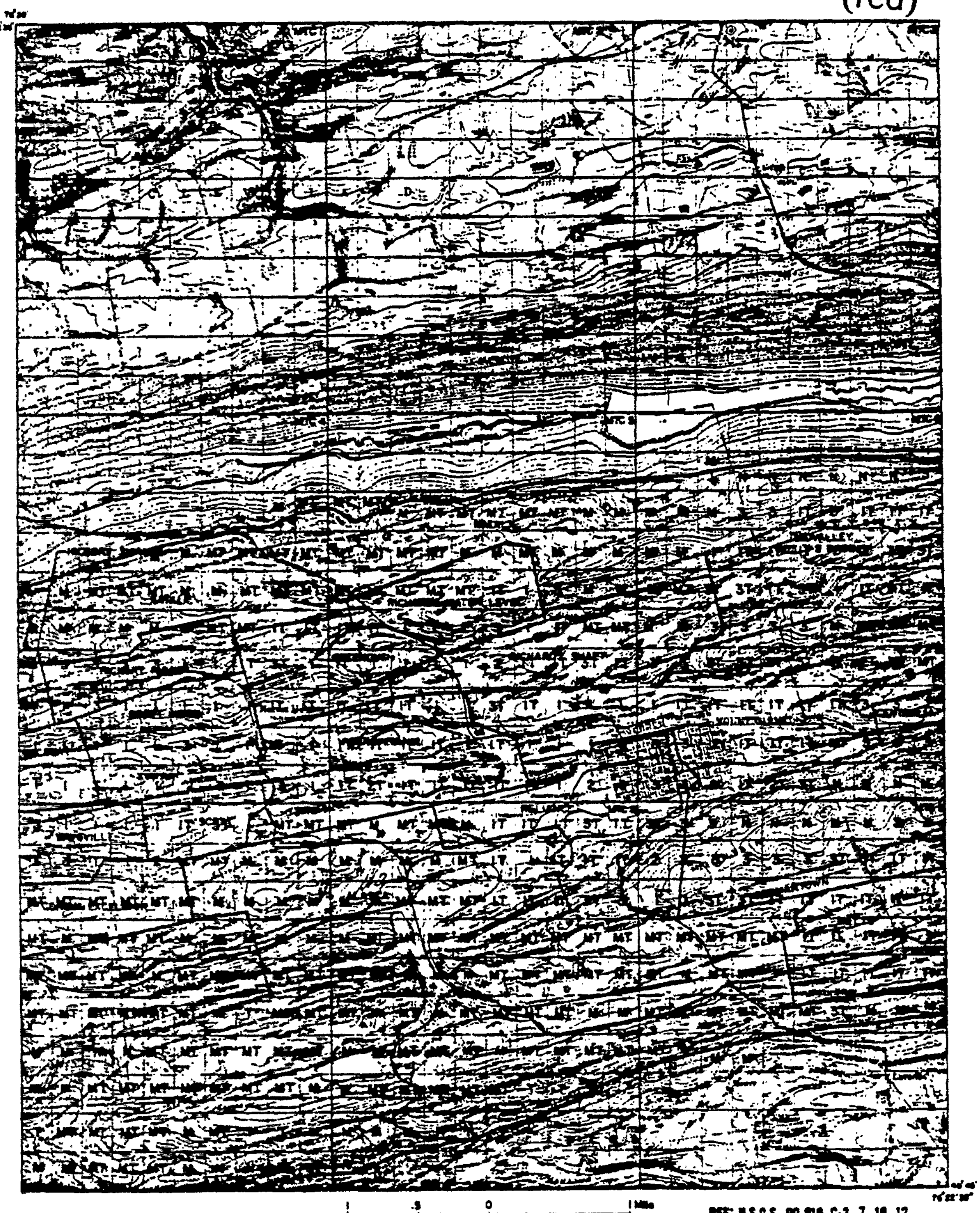
THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

FIGURE 42 SHAMOKIN QUADRANGLE

74-144

ORIGINAL

(red)



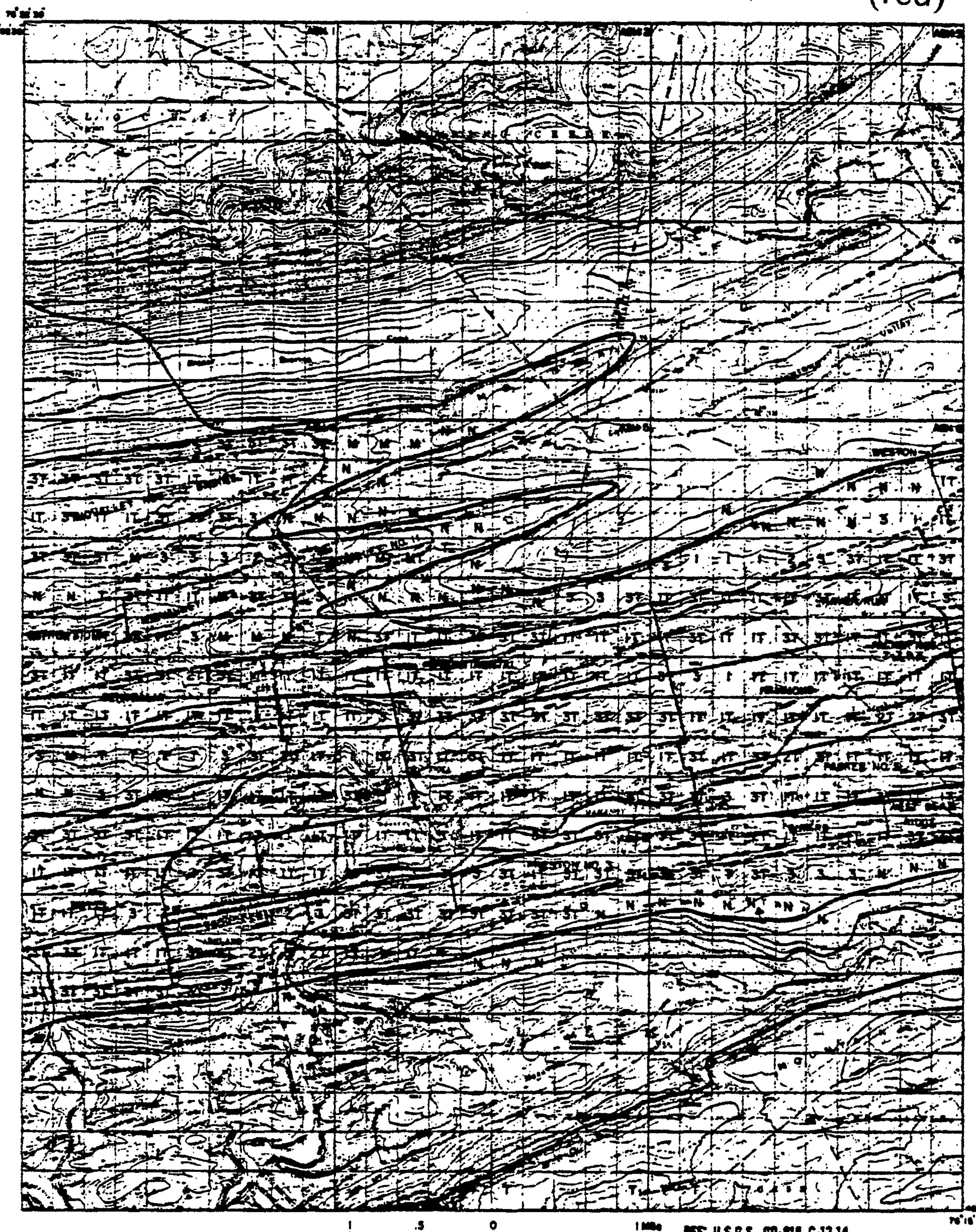
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

SCALE

REF: U.S.G.S. GQ-919, C-3, 7, 10, 12

FIGURE 43 MOUNT CARMEL QUADRANGLE

74-144



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

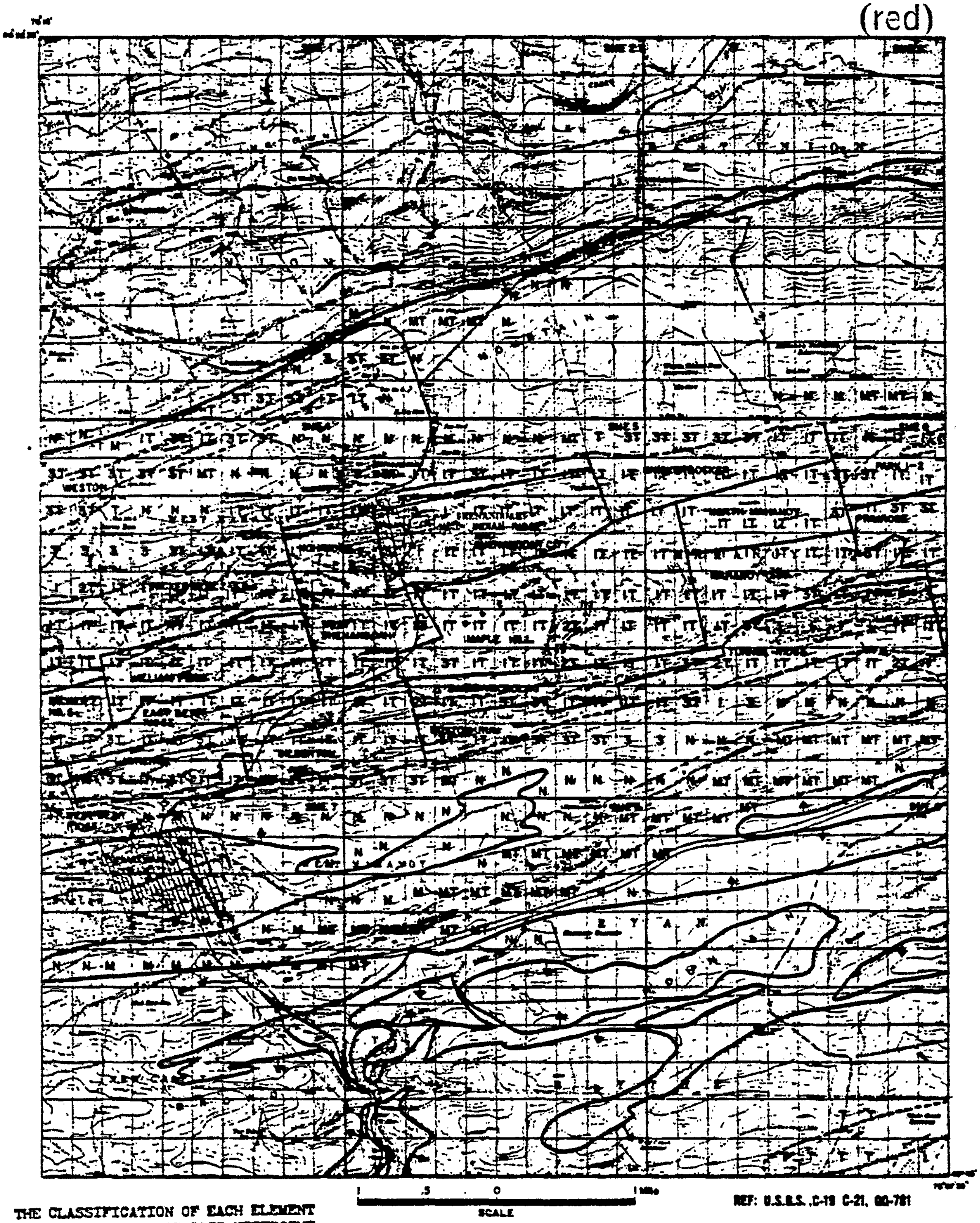
1 .5 0 1 Mile
SCALE

REF: U.S.G.S. GQ-918, C-13,14

FIGURE 44 ASHLAND QUADRANGLE

74-144

ORIGINAL
(red)

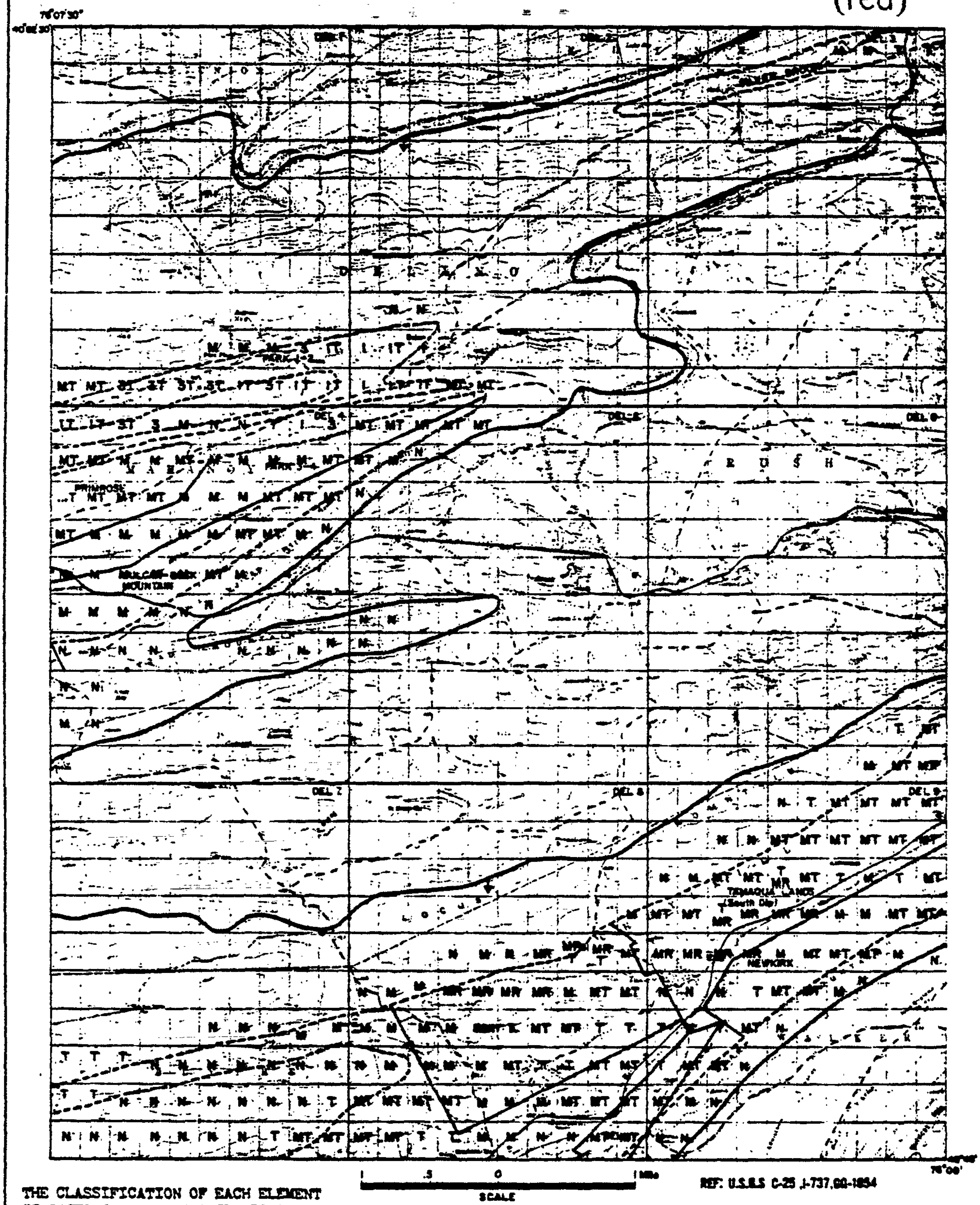


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 45 SHENANDOAH QUADRANGLE

74-144

ORIGINAL
(red)



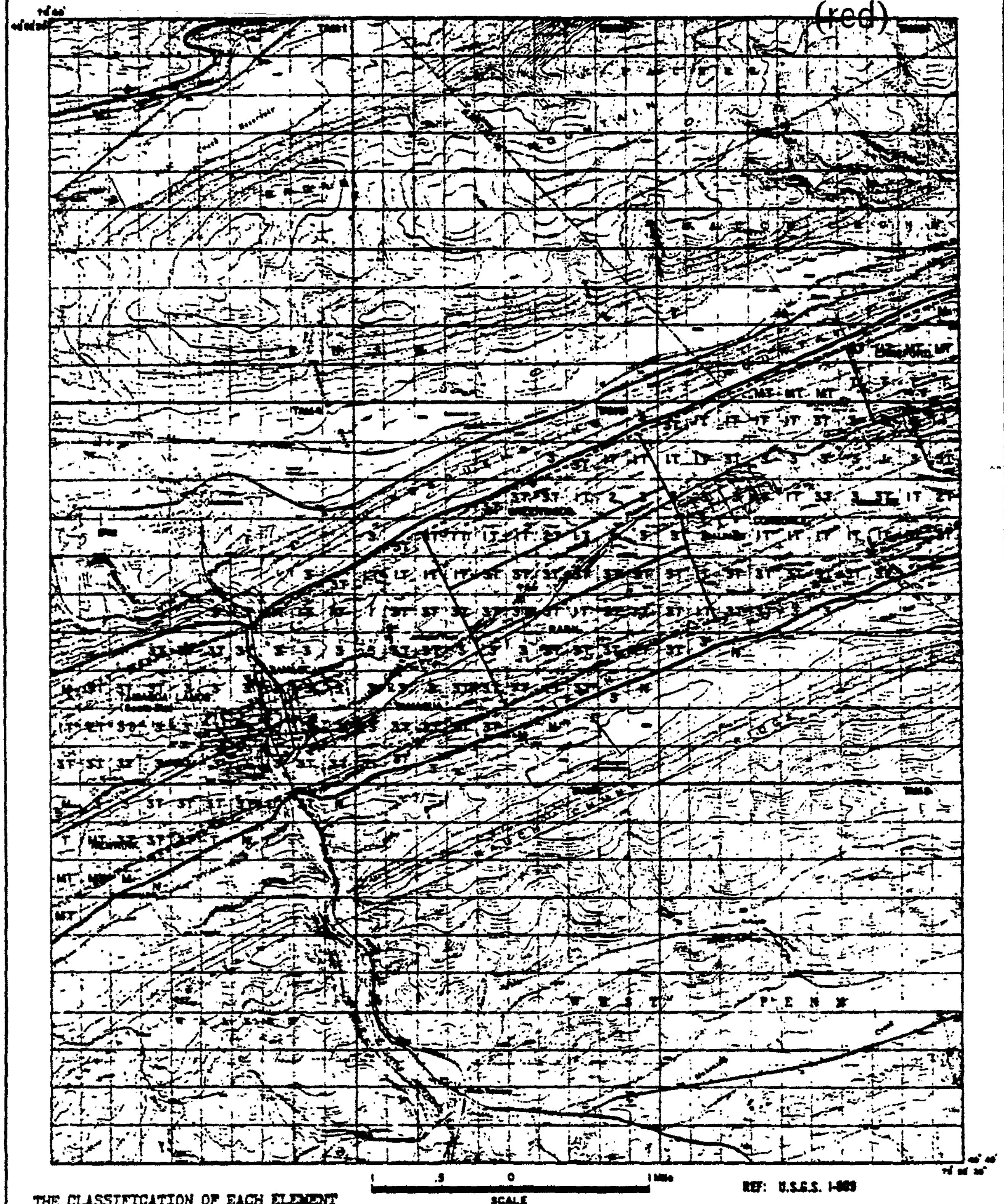
REF: U.S.G.S C-25 ,I-737,00-1954

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 48 DELANO QUADRANGLE

ORIGINAL

(red)



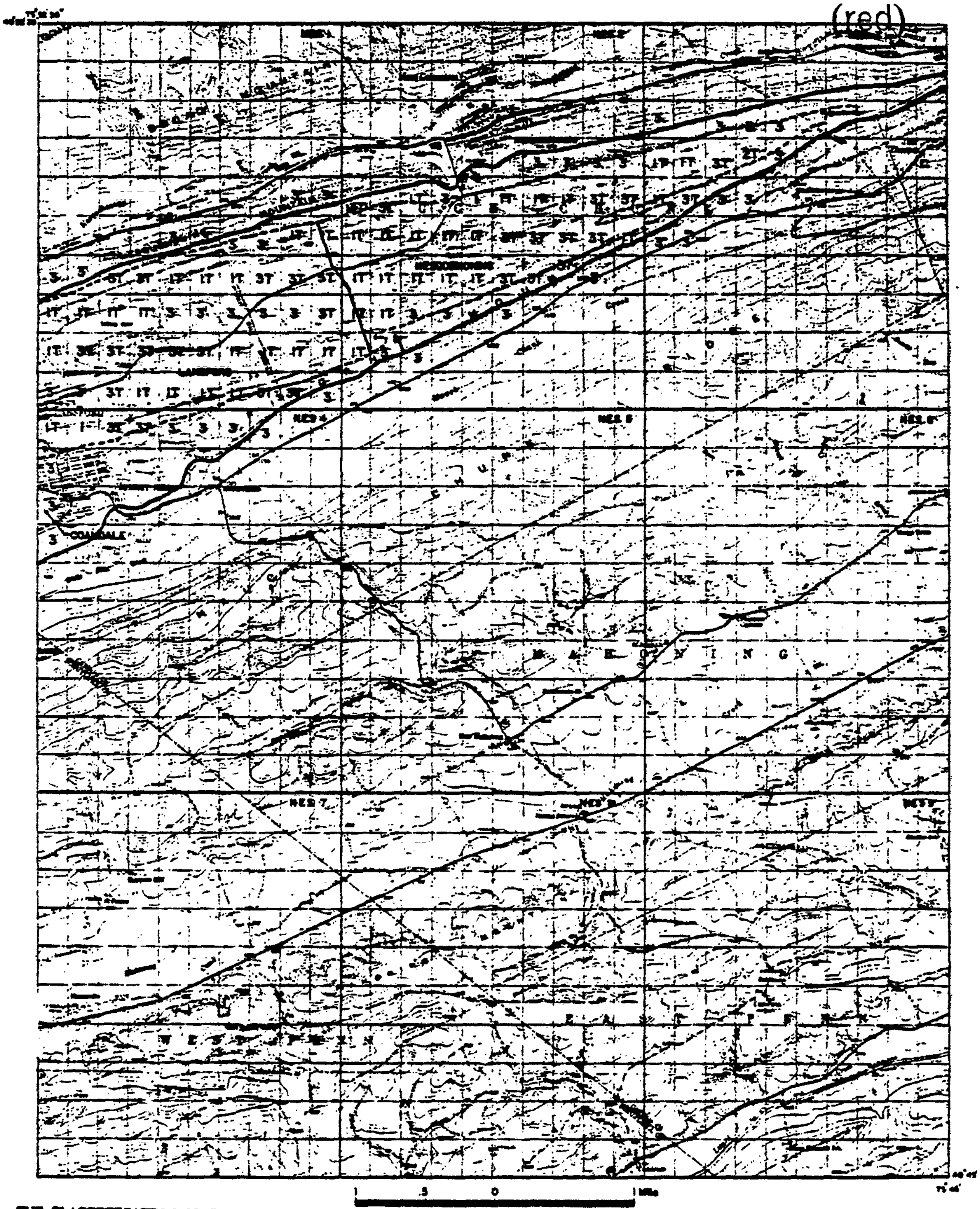
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 47 TAMAQUA QUADRANGLE

REF: U.S.G.S. I-889

74-144

ORIGINAL
(red)



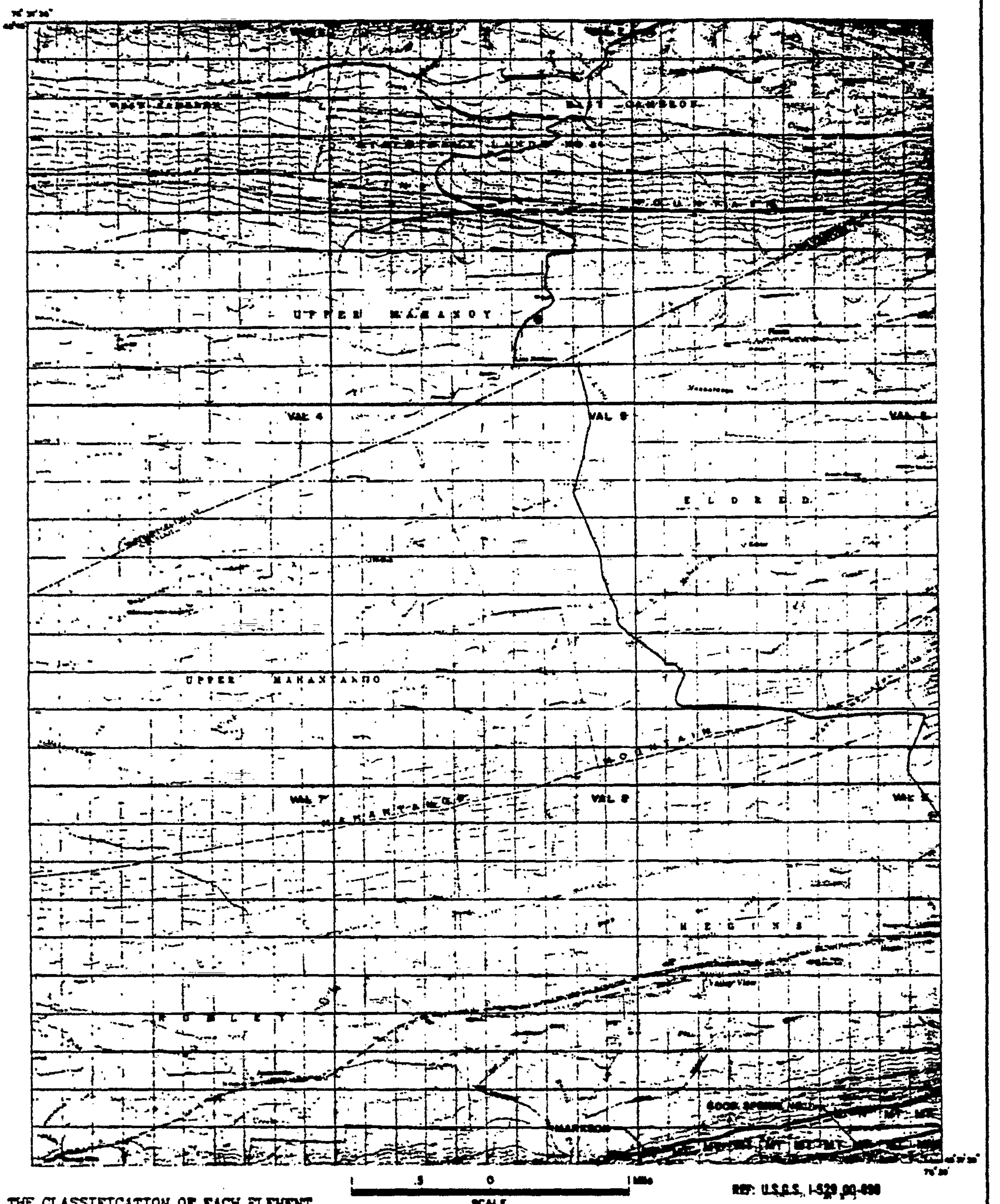
THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 48 NESQUEHONING QUADRANGLE

74-144

AR100150

ORIGINAL
(red)

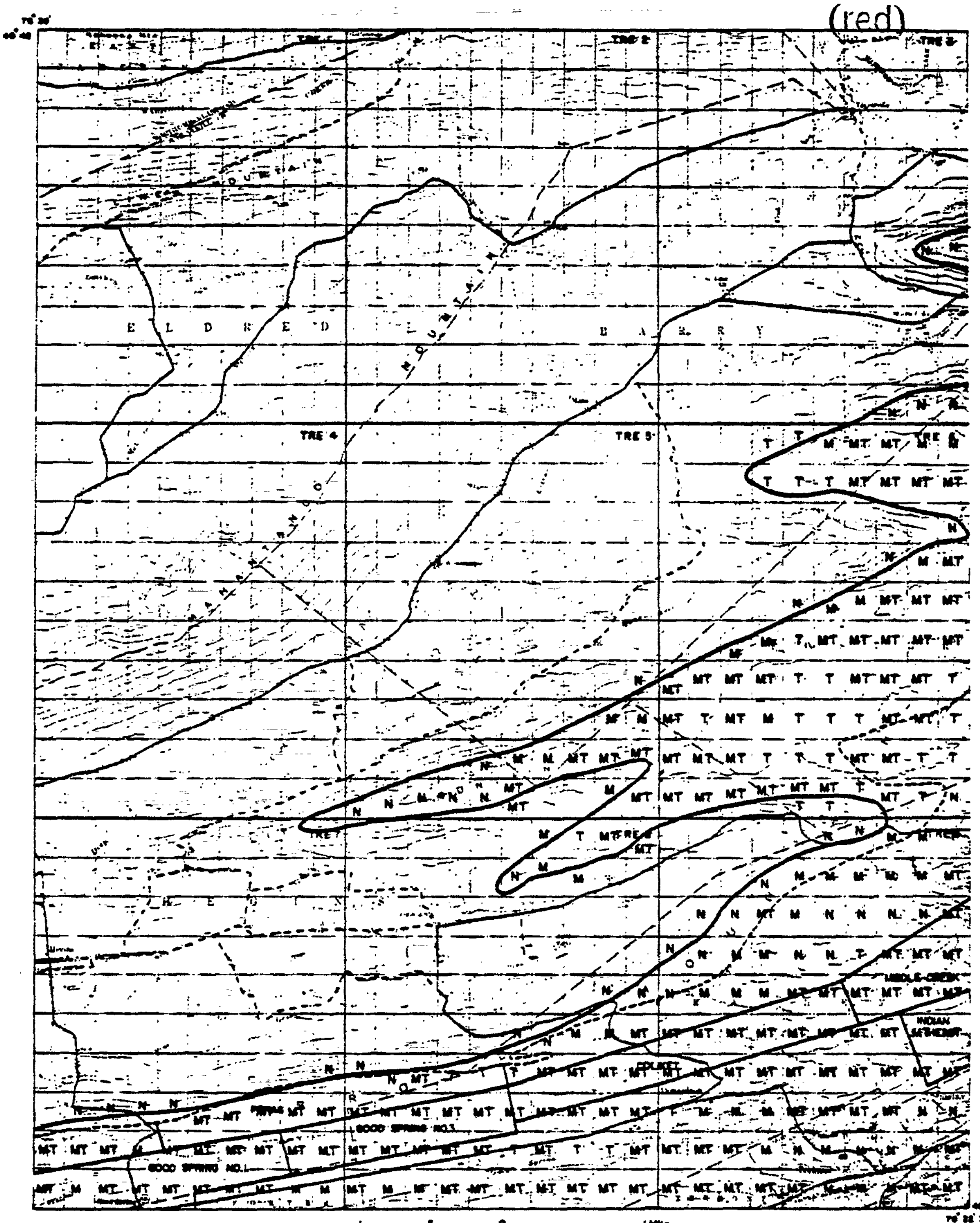


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 49 VALLEY VIEW QUADRANGLE

76-144

ORIGINAL (red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

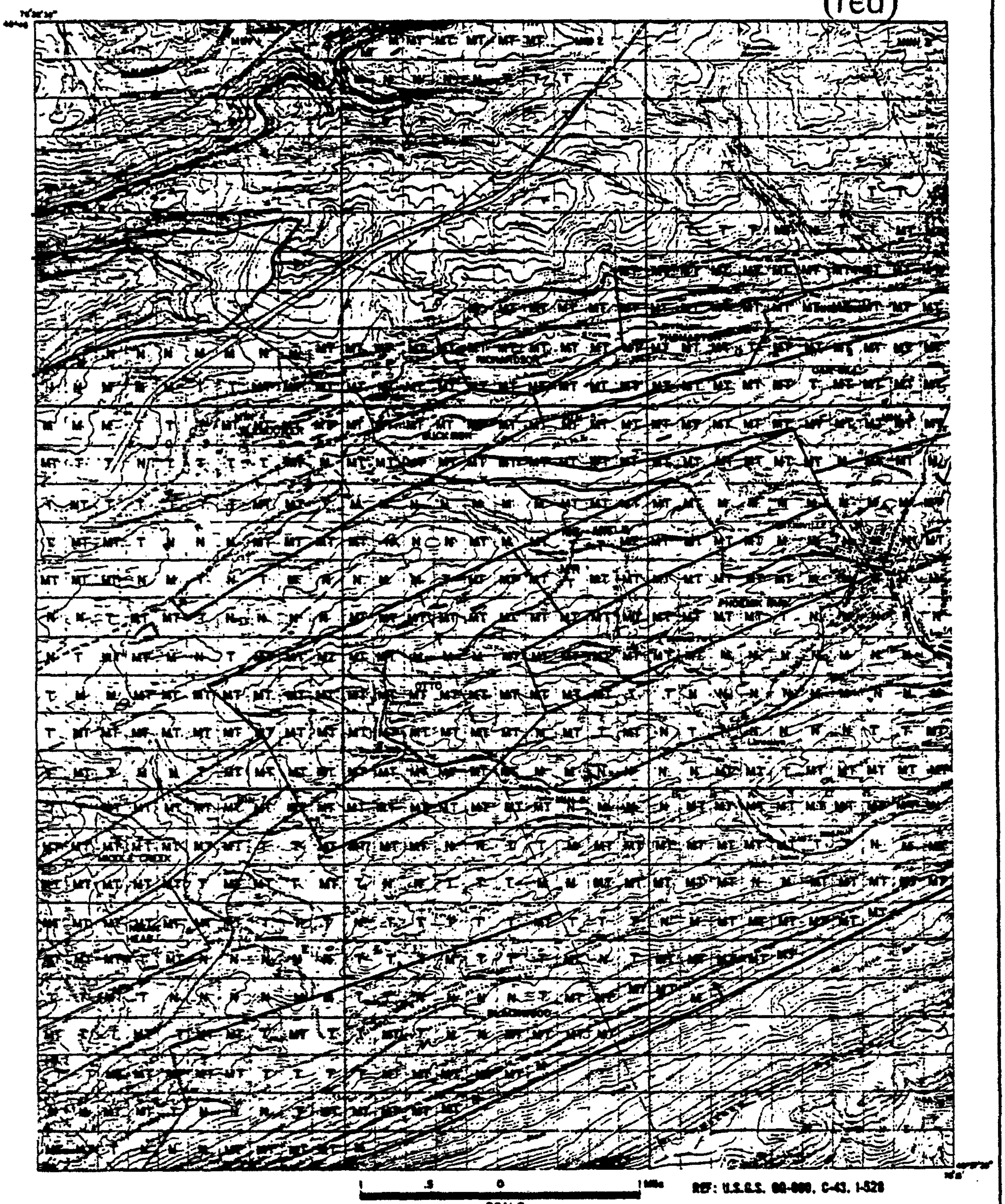
FIGURE 50 TREMONT QUADRANGLE

74-144

AR100152

ORIGINAL

(red)

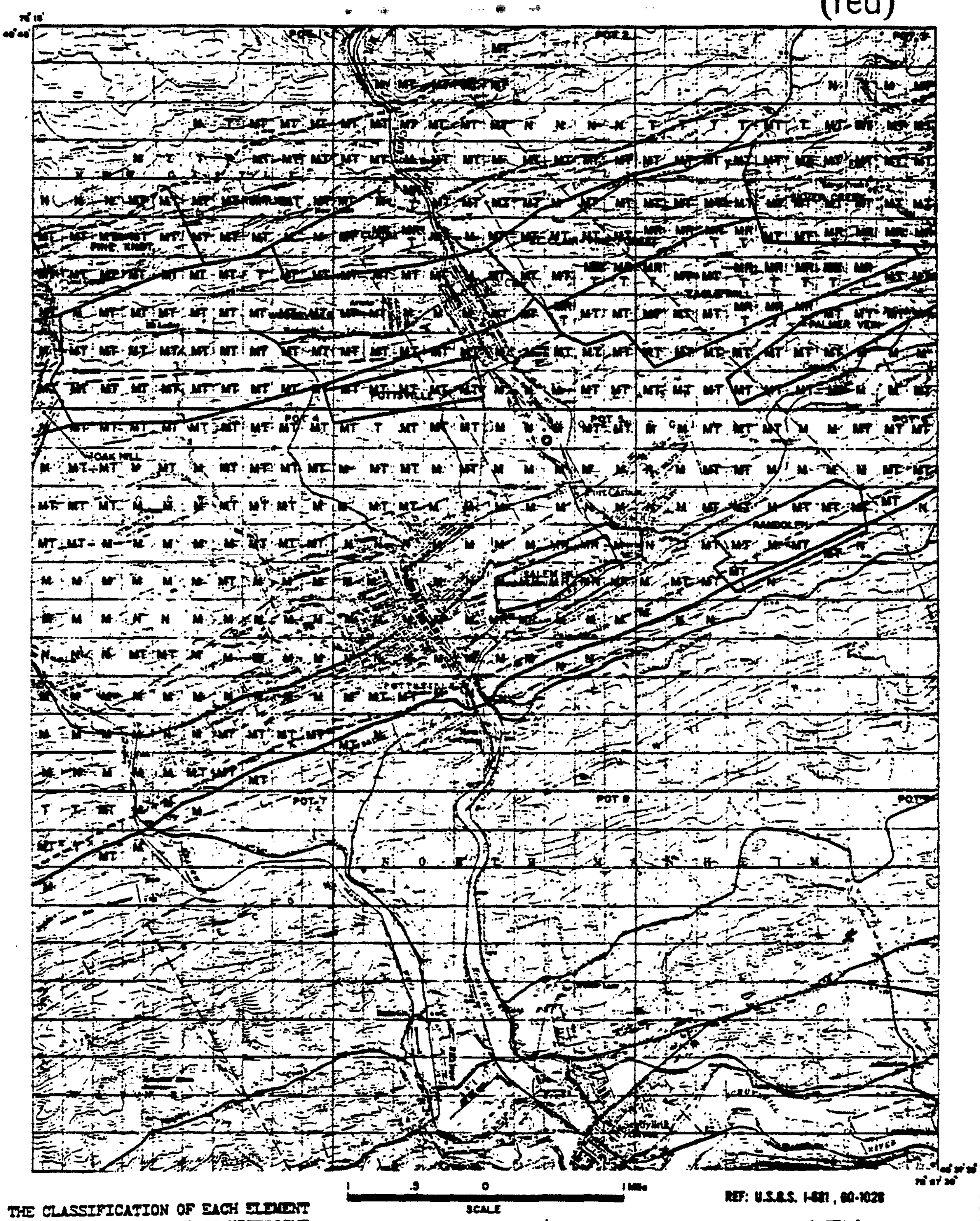


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 51 MINERSVILLE QUADRANGLE

76-144

ORIGINAL
(red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

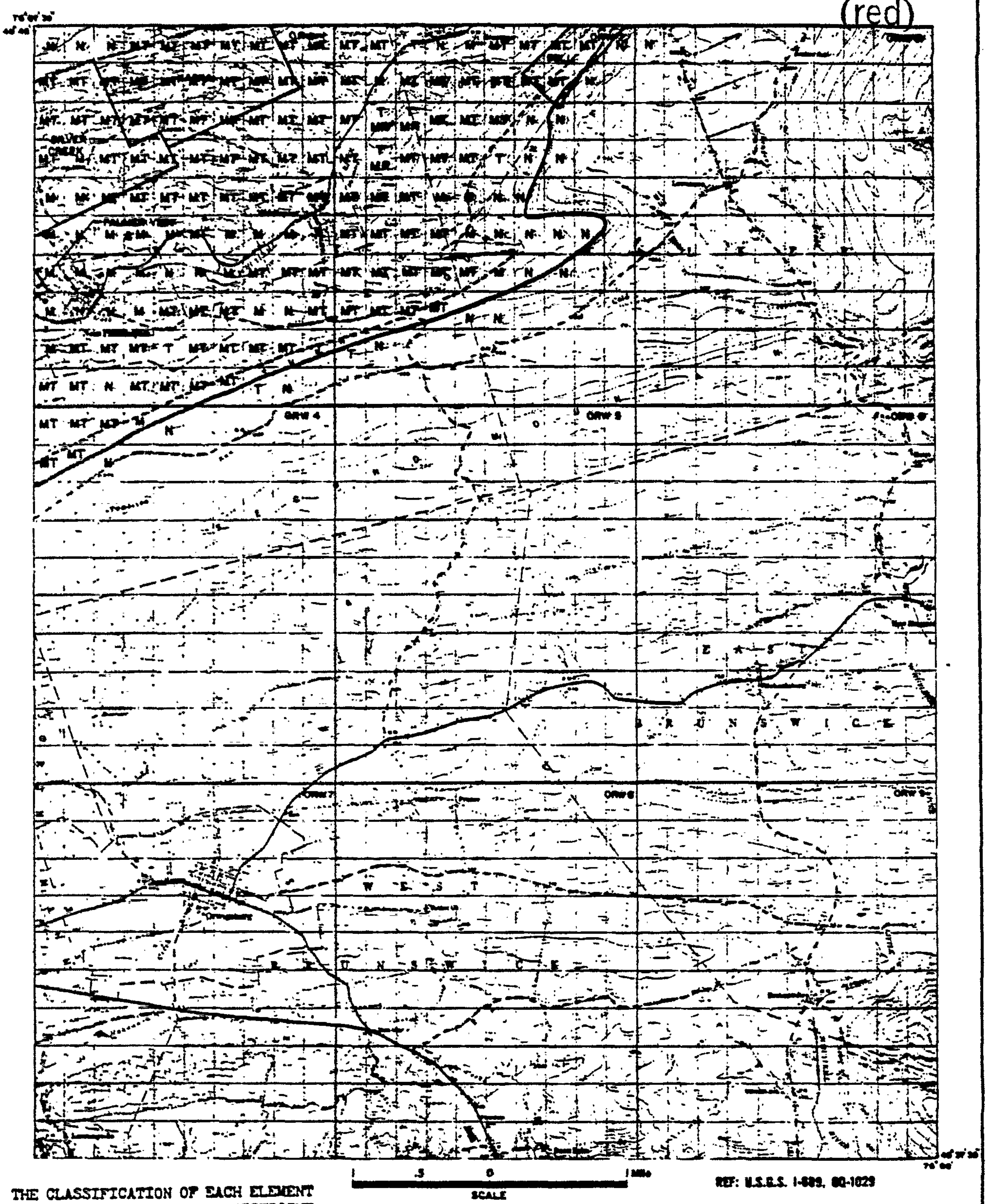
FIGURE 52 POTTSVILLE QUADRANGLE

74-144

AR100154

ORIGINAL

(red)



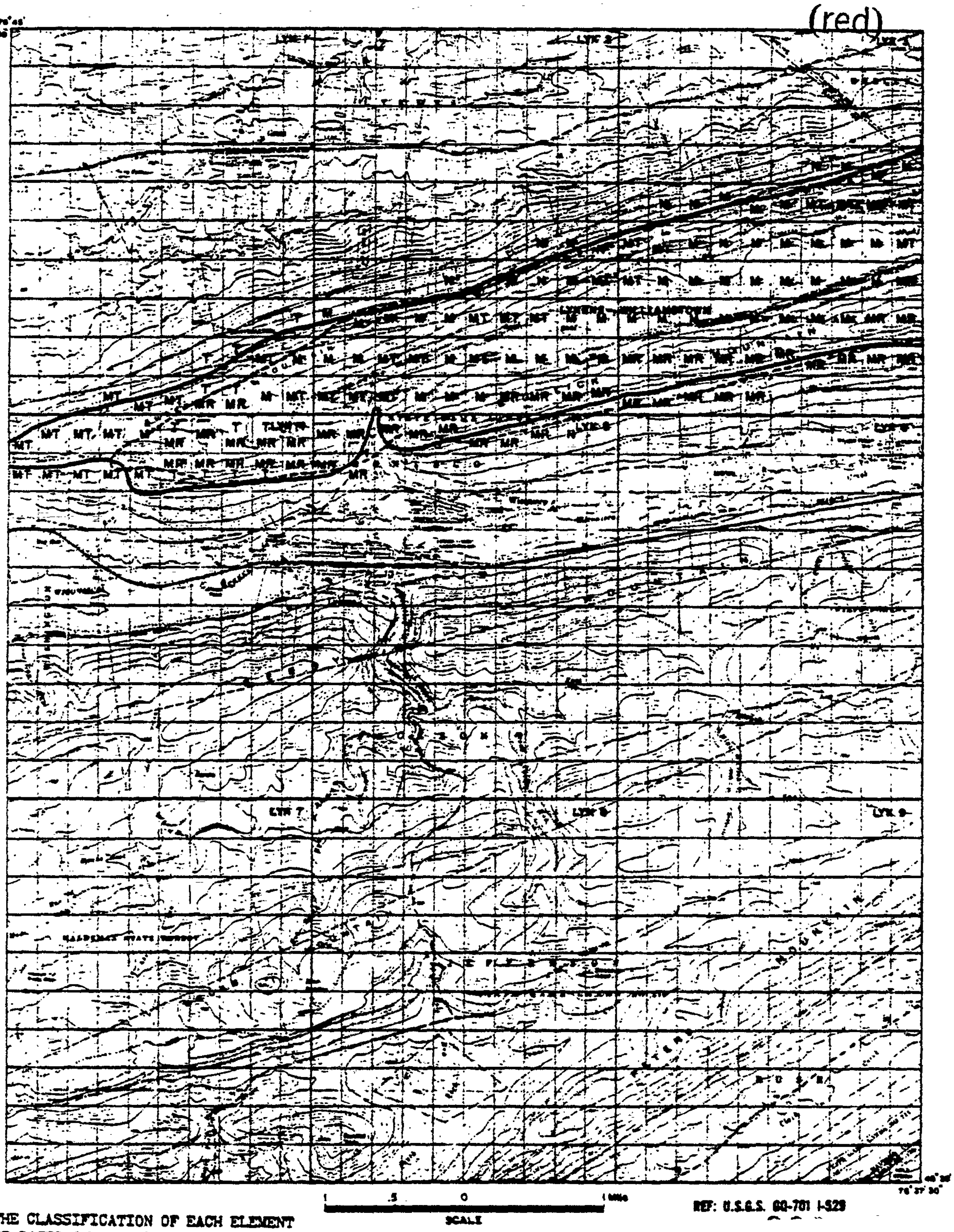
THE CLASSIFICATION OF EACH ELEMENT
IS BASED ON A WORST CASE VIEWPOINT
OF 10% OF THE ELEMENT.

REF: U.S.G.S. I-689, GQ-1029

FIGURE 53 ORWIGSBURG QUADRANGLE

76-144

ORIGINAL (red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

REF: U.S.G.S. GQ-701 I-529

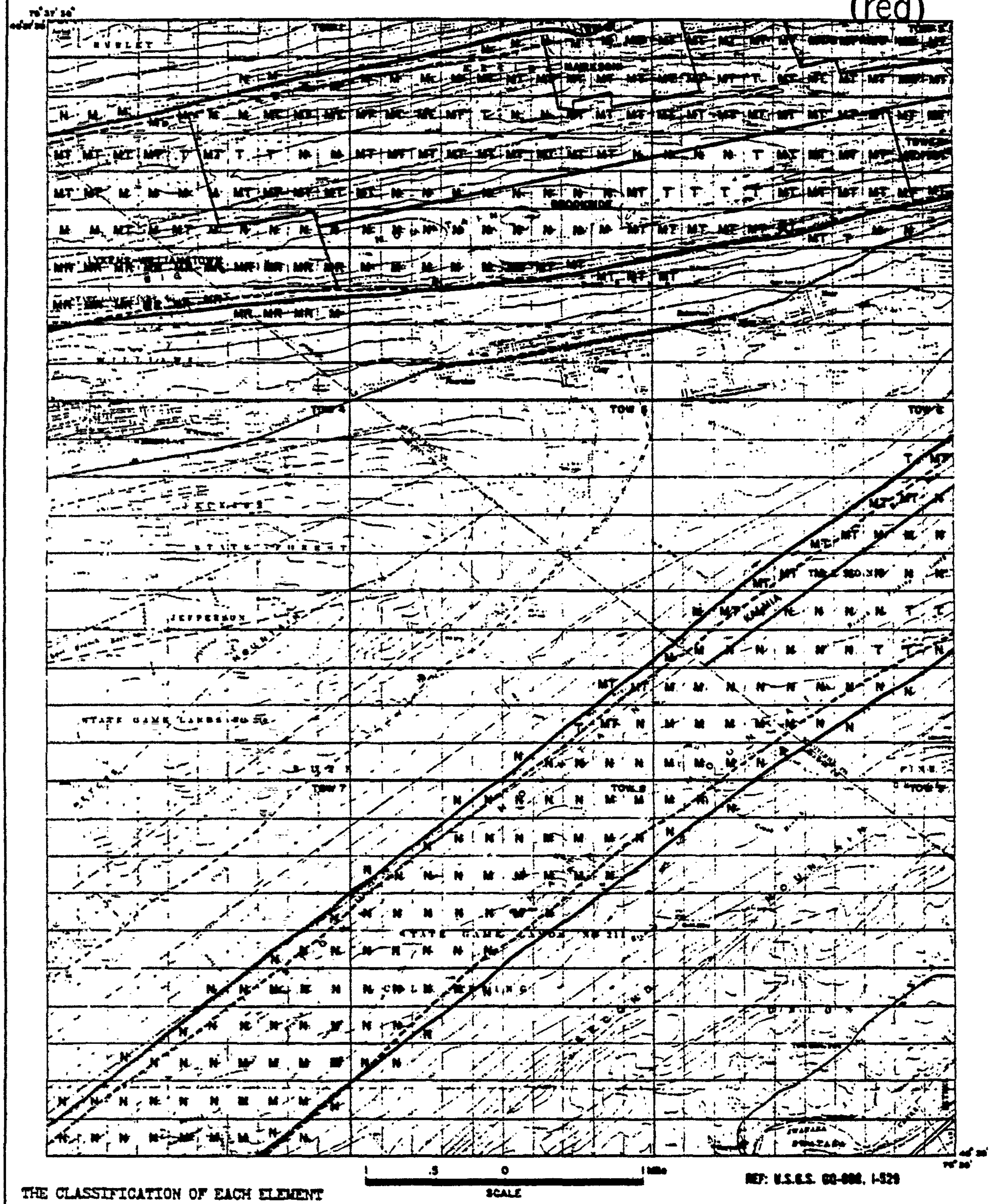
FIGURE 54 LYKENS QUADRANGLE

76-144

AR100156

ORIGINAL

(red)

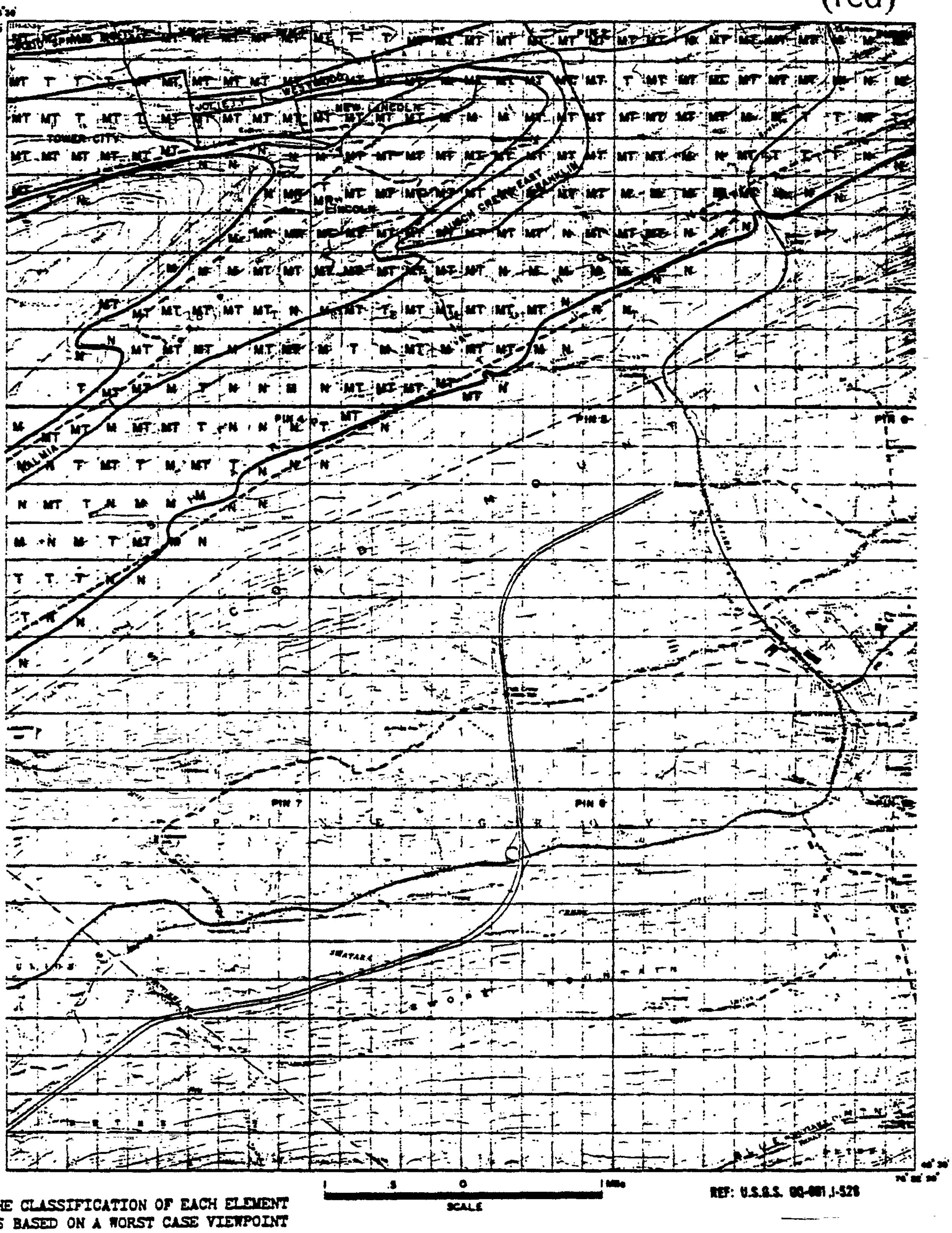


THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 55 TOWER CITY QUADRANGLE

ORIGINAL

(red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

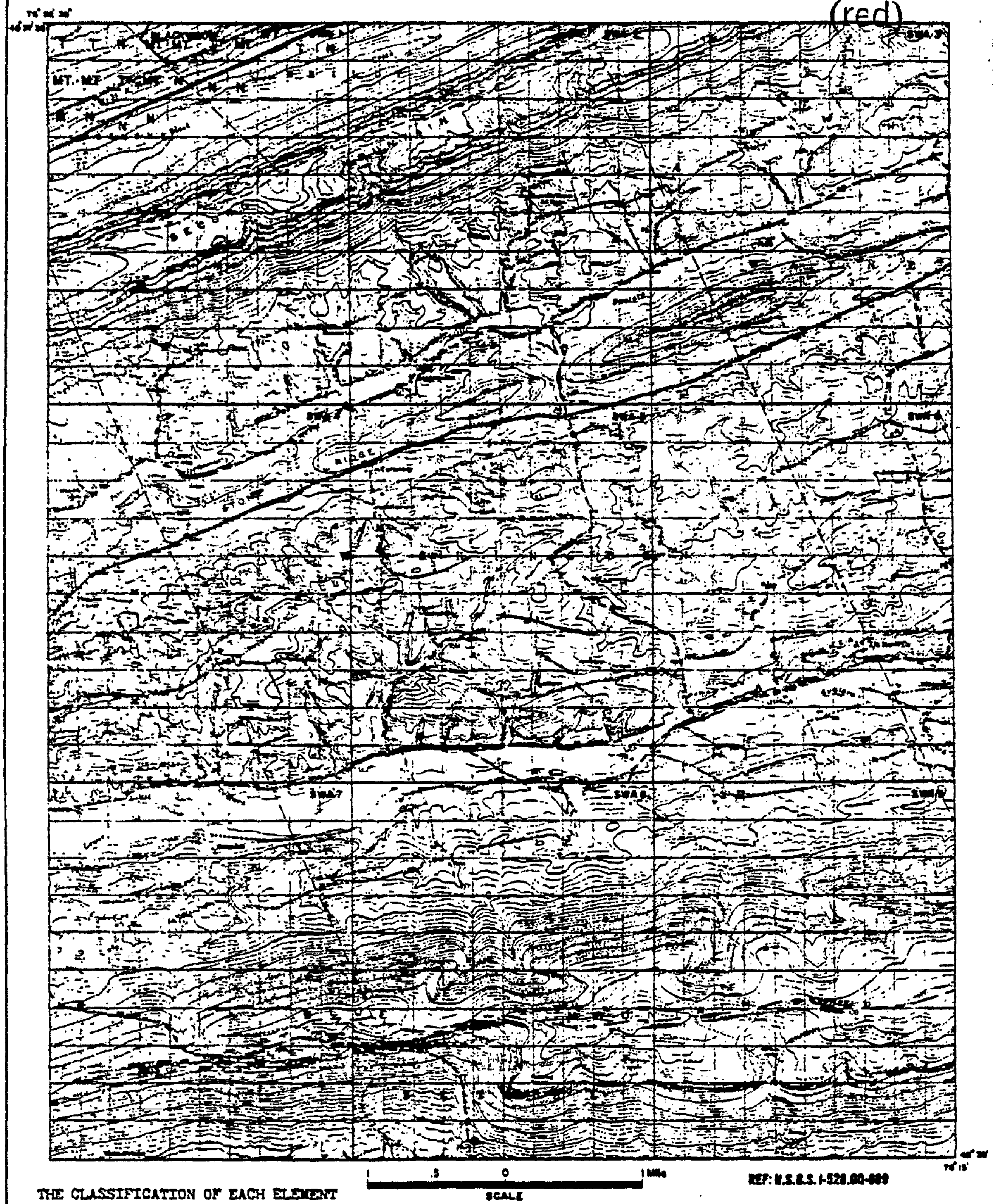
SCALE

REF: U.S.G.S.

FIGURE 56 PINE GROVE QUADRANGLE

ORIGINAL

(red)



THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

FIGURE 57 SWATARA HILL QUADRANGLE

74-144

AR100159

3.3.3 Bituminous Testing. The subsidence computer algorithm (SEAMS) was tested in two localities within the Bituminous coal fields of Appalachia. This was done to illustrate the applicability of the technique which was developed exclusively in the Anthracite fields of northeastern Pennsylvania. The localities were chosen on the availability of mine maps and one site in Centre County, Pennsylvania and one site in Allegany County, Maryland served as the test sites.

Mine maps were located in the HRB-Singer, Inc. archives for the Knowles, Big Spring #1, and Harpster Mines. These three abandoned mines are located in western Centre County, Pennsylvania in the Sandy Ridge Quadrangle. All three mines were single seam operations in the Clarion or "A" seam, the basal coal in the Allegheny Series (See Table 2, Section 1.4.2 of this report).

The SEAMS algorithm was applied to 13 elements of Section 1 of the Sandy Ridge Pennsylvania Quadrangle with results shown in Table 16 and in Figure 58.

Mine maps were obtained from the Pittsburgh Office of the U.S.B.M. for the abandoned Consol #1 and adjacent mines in Allegany County, Maryland. Generalized geologic and mining information maps were supplied by Gannet, Fleming, Corddry, and Carpenter, Inc. These mine maps cover underground workings in the Pittsburgh or Big Vein seam and include stripping and some underground workings in the overlying Sewickly seam. These coals are included in the Monongahela series (upper Pennsylvanian) and represent younger coals not present in the Anthracite region.

The SEAMS algorithm was applied to 20 elements of Section 2 of the Lonaconing, Maryland Quadrangle with the results shown in Table 17 and in Figure 59.

The results of the testing program are as expected in that the algorithm is treating data similar to that received from the Anthracite Fields. Similar results were obtained, and on this basis there is no reason to believe that SEAMS (subject to the limitations discussed in Section 3.2 of this report) cannot be applied to any other coal mining area within the Appalachian Region.

ORIGINAL

(red)

TABLE 18 BITUMINOUS TESTING RESULTS, SANDY RIDGE QUADRANGLE, PENNSYLVANIA AND LONACONING QUADRANGLE, MARYLAND

74-144

SANDY RIDGE, PENNSYLVANIA QUADRANGLE (SAN 1)		
ELEMENT #	SUBSIDENCE CLASS	TS_{MAX}
C8	2	0.25
C9	2	0.09
D8	2	0.50
D9	2	0.18
D0	1	2.82
E7	2	0.10
E8	1	0.54
E9	1	1.77
E0	1	1.53
F7	1	2.16
F8	2	0.39
F9	1	0.85
F0	3	0.00
LONACONING, MARYLAND QUADRANGLE (LON 2)		
D1	1	6.8
D2	1	6.8
D3	1	6.8
D4	1	6.8
E1	1	6.8
E2	1	6.8
E3	1	6.8
E4	1	9.1
F1	1	9.1
F2	1	6.8
F3*	1	6.8
F4	1	9.1
G1	1	6.8
G2	1	6.8
G3*	1	6.8
G4*	1	4.3
H1*	1	6.8
H2*	1	6.8
H3*	1	6.8
H4*	1	4.3

*REPORTED SUBSIDENCE

ORIGINAL

(red)

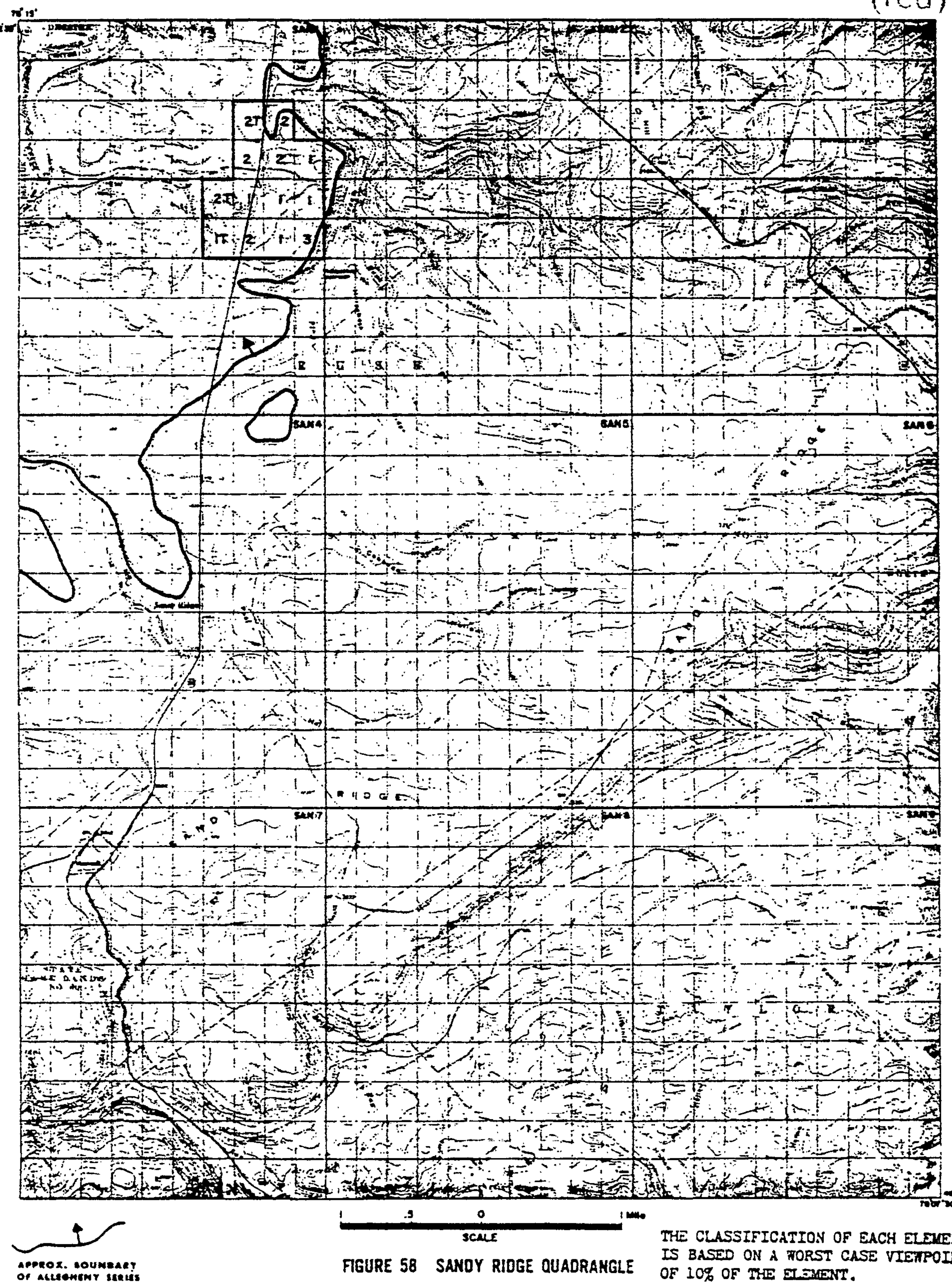


FIGURE 58 SANDY RIDGE QUADRANGLE

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

74-144

ORIGINAL

(red)

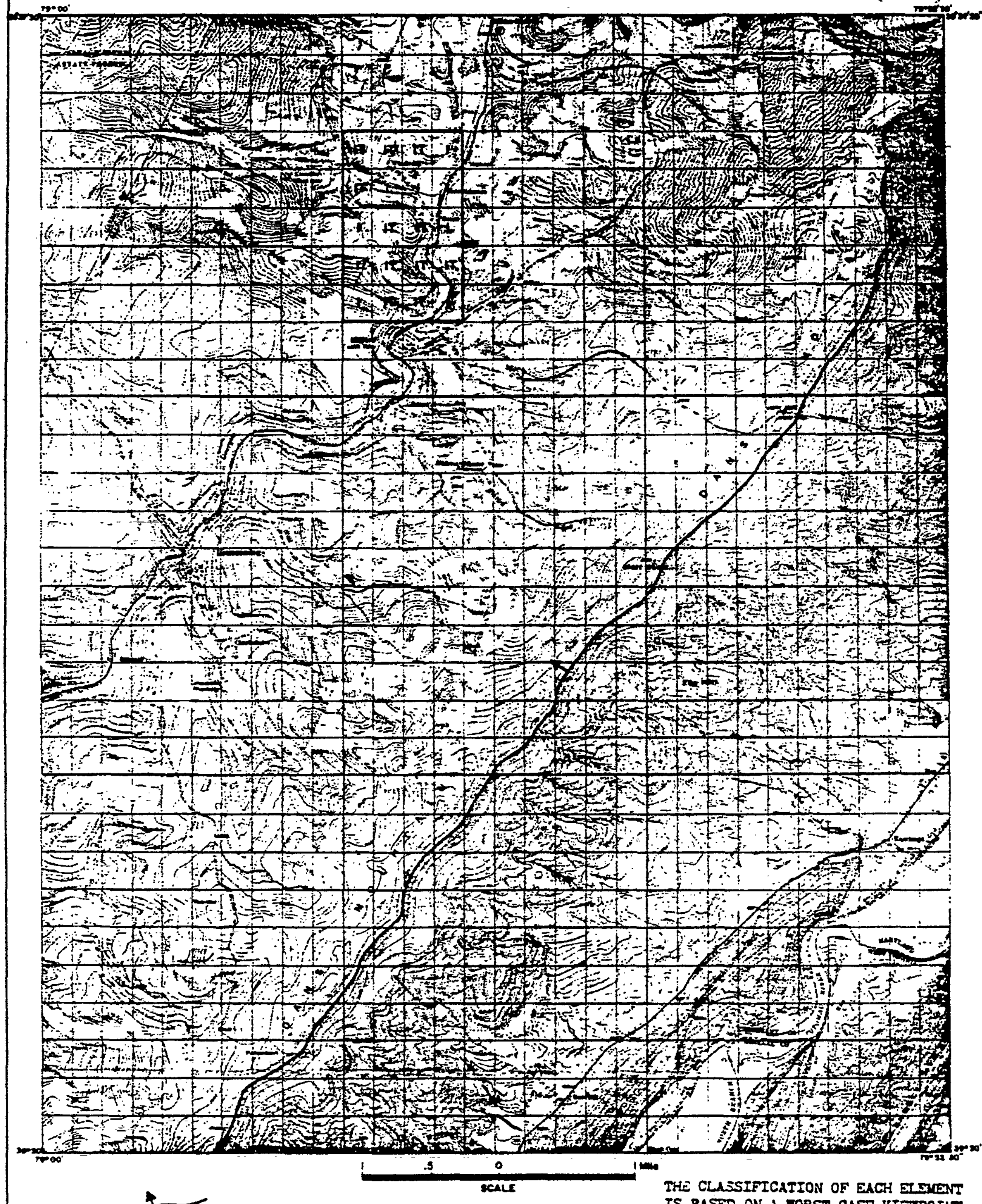


FIGURE 59 LONACONING QUADRANGLE

APPROXIMATE BOUNDARY OF PENNSYLVANIAN COAL FIELD

THE CLASSIFICATION OF EACH ELEMENT IS BASED ON A WORST CASE VIEWPOINT OF 10% OF THE ELEMENT.

74-144

AR100163

4. RECOMMENDATIONS

On the basis of the results and conclusions reached in this study it is recommended that:

(1) Continued efforts be initiated to incorporate additional mine map data into the data base as it becomes available. This is particularly important for the Eastern Middle Field and those areas of the Western Middle and Southern Fields where mine map data has not yet been incorporated into folios by the USBM. Additional data such as burning refuse banks, and coal seam fires could easily be entered into the data base, as well as the extent of recent surface stripping.

(2) The existing data base be exercised to extract regional data on the extent of mining on a seam by seam basis and that other parameter information be used in the form of map displays. Such displays could for example include seam percentage extraction maps, seam thickness maps, seam elevation maps, depth to bedrock maps.

(3) Continued refinement and testing of the algorithm be undertaken to prove its accuracy and to extend its use into the Bituminous coal fields of Appalachia. Further work is needed to incorporate the effect of steeply dipping strata into the algorithm. Additional work is needed on the correlation between reported subsidence areas and the underlying mining conditions; an analysis of the relationship between known subsidence areas and the critical parameters to answer the question "which of the critical parameters were responsible for the subsidence?"

(4) Consideration should be given to the collection of more detailed mining information within specific 40 acre elements selected on the basis of priority. These priorities can be established using the present map products and correlating them with areas of concentrated urban development, either current or anticipated, and with those areas presently identified for construction of industrial or public facilities. The basic elemental area most appropriate for meaningful and cost effective correlation with reported subsidence occurrences should be studied within high priority areas. Ten acre and smaller elements should be considered for areas of concentrated land use or urban development. This is especially critical to

minimize the impact of subsidence considerations on future economic development within the mining areas of Pennsylvania and to support studies of a more site-specific nature. The use of this basic data base as a model is useful in making such collection uniform and systematically assessable by computer.

ORIGINAL (red)

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5.1 REFERENCES CITED

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5.2 MAPS

5.2.1 <u>Coal Investigations Maps U.S. Geological Survey C-Series.</u>

Map C-3 Rothrock, H. E., Wagner, H. C., Haley, B. R., 1950, Geology of Anthracite in the West-Central Part of Mount Carmel Quadrangle, Pennsylvania Survey.

ORIGINAL

Map C-7 Rothrock, H.E., Wagner, H.C., Haley, (rec'd) B.R., and Arndt, H.H., Geology of Anthracite in the Southwestern Part of the Mount Carmel Quadrangle, Pennsylvania.

Map C-10 Rothrock, H.E., Wagner, H.C., Haley, B.R. and Arndt, H.H., 1951, Geology of Anthracite in the East-Central Part of the Mount Carmel Quadrangle, Pennsylvania.

Map C-12 Rothrock, H.E., Wagner, H.C., Haley, B.R. and Arndt, H.H., 1953, Geology of Anthracite in the Southeastern Part of the Mount Carmel Quadrangle, Pennsylvania.

Map C-13 Haley, B.R., Arndt, H.H., Rothrock, H.E., Wagner, H.C., 1953, Geology of Anthracite in the Western Part of the Ashland Quadrangle, Pennsylvania.

Map C-14 Haley, B.R., Arndt, H.H., Rothrock, H.E., Wagner, H.C., 1954, Geology of Anthracite in the Eastern Part of the Ashland Quadrangle, Pennsylvania.

Map C-19 Kehn, T.M. and Wagner, H.C., Geology of Anthracite in the Eastern Part of the Shenandoah Quadrangle, Pennsylvania.

Map C-21 Dawilchik, W., Rothrock, H.E., Wagner, H.C., 1955, Geology of Anthracite in the Western Part of the Shenandoah Quadrangle, Pennsylvania.

Map C-25 Maxwell, J.A. and Rothrock, H.F., 1955, Geology of Anthracite in the Western Part of the Delano Quadrangle, Pennsylvania.

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APPENDIX A

The text of this report concludes at this point. The following Appendix A represents the personal opinions of Mr. Daniel H. Connelly, Professional Mining Engineer and former Secretary of the Department of Mines and Mineral Industries and is included at the request of the Economic Development Council of Northeastern Pennsylvania. The Department of Environmental Resources assumes no responsibility for information contained in this Appendix. Any questions regarding information contained in this Appendix should be addressed to the Economic Development Council of Northeastern Pennsylvania. The figures for maximum projected subsidence referred to by Mr. Connelly are contained upon maps on file with the Department of Environmental Resources and with the State Library, Harrisburg, Pennsylvania.

For the purpose of determining the accuracy of the Subsidence Vulnerability Classification on Quadrangle Maps with reference to the three categories in which the land elements are classified, particularly "Class 1" situations, seventeen locations, in which the writer has had personal experience, were selected. Three of the locations are included on the Scranton Quadrangle Map; two on the Olyphant Quadrangle Map; three on the Avoca Quadrangle Map; one on the Kingston Quadrangle Map; four on the Pittston Quadrangle Map; practically all of the City of Nanticoke; two on the Wilkes-Barre West Quadrangle Map; one on the Wilkes-Barre East Quadrangle Map.

The results of the study are as follows:

ITEM I. The subsidence vulnerability for the Borough of Taylor, Lackawanna County, is included on the Scranton Quadrangle Map. As closely as I could determine there are 140-40 acre elements included on the map which are in the Borough of Taylor. Of the total of 140, 133 or 95% of the total are in Class 1, three are in Class 2, and four are in Class 3.

My experience with the underground conditions underlying the Borough of Taylor are in connection with a flushing project underlying the right-of-way of the Northeastern Extension of the Pennsylvania Turnpike which was undertaken in the years 1955 to 1956. Involved was a strip which varied from 400' to 500' in width where a series of boreholes were drilled fifty feet apart to the right and left of the center line of the Turnpike, there being nine boreholes in a 400 foot width and eleven boreholes in a 500 foot width. There was a series of boreholes every 50 feet along the Turnpike right-of-way.

The holes were drilled from the surface to the lowest or bottom vein, a depth of approximately 200 to 250 feet. The area involved was from the westerly bank of the Lackawanna River to Keyser Avenue.

When the flushing project was started it was found that the underground area was caved to the extent that the hole would accept an amount equal only to the amount of cuttings from the drilling of the boreholes. The removal of the pillars underlying the Turnpike area has been completed 20 to 30 years prior to the attempt to flush.

All of this area is included under Class 1 and the projected subsidence varies from a low of 1.3 feet for one element to a variance of 10.6 feet to 16.3 feet for the remaining 15 elements.

(Scranton Quadrangle, block 7, elements F5, G5, H5, I6, 7, J7)

ITEM II. This involves the recently dedicated Stauffer Industrial Park. The area is designated as Class 1 on the map. The projected subsidence varies from 6.3 feet to 13.3 feet through six 40 acre elements.

There are three mining reports from Registered Professional Mining Engineers on this site, one dated 1951, another dated 1961, and the third 1966. Each report is favorable.

(Scranton Quadrangle, block 8, elements C1,2,2; D1, 2, 3)

ITEM III. This involves the Mall on Route 6 just northeast of its intersection with Interstate No. 81, known as Viewmont Mall. The area is designated as Class 1 on the map. The projected subsidence varies from 6.4 feet to 9.1 feet.

There is a favorable report from a Registered Professional Mining Engineer for this site.

(Scranton Quadrangle, block 3, elements H4, J4) ORIGINAL (red)

ITEM IV. This involves Keystone Industrial Park. The area is designated as Class 1 on the map. The projected subsidence varies from 8.1 feet to 8.7 feet.

There are three mining reports from Registered Professional Mining Engineers on this site, one dated 1959, another 1960 and the third 1965. Each report is favorable.

(Avoca Quadrangle, block 1, elements G7, 8; H6, 7, 8; I5, 6, 7)

ITEM V. This involves the area occupied by the former Eureka Plant of Litton Industries. The area is designated as Class 1 on the map. The projected subsidence is 1.3 feet.

There was never any mining in this area as the bottom coal seam crops out below this site.

(Olyphant Quadrangle, block 4, element J6)

ITEM VI. This involves the Wilkes-Barre/Scranton Airport. The area is designated as Class 1 on the map. The projected subsidence varies from 0.3 feet to 4.3 feet.

In 1943 I was a member of a 3 man commission appointed by the Secretary of Mines of the Commonwealth to make an underground inspection of the mine workings underlying the surface where the present airport is located. This was at the request of the Federal Aviation Administration. A report was later filed with the State and Federal Agencies. Certain recommendatins were included in the report and the report and recommendations were accepted by the Federal Aviation Administration and after a contract for the construction of the Port was awarded I was designated by the Secretary of Mines to make periodic inspections for the purpose of determining that the recommendations were being carried out. The port has been in use for approximately 30 years and I have never heard of a subsidence affecting any of the runways.

(Avoca Quadrangle, block 1, elements G7, 8; H6, 7, 8; I5, 6, 7; J6, 7; block 4, elements A5, 6, 7)

ITEM VII. This involves the site on which the "Topps Plant" is situated in the Borough of Duryea. The area is designated as Class 1 on the map. The projected subsidence is listed as 8.8 feet.

There is a mining report for this site dated March 23, 1965 by a Registered Professional Mining Engineer which includes the information that there has been complete mining in all veins underlying the surface, the final mining having been in the year 1946.

(Avoca Quadrangle, block 1, elements F1, G1)

ITEM VIII. This involves the site on which the "Schott Optical Plant" is situated in the Borough of Duryea. The area is designated as Class 1 on the map. The projected subsidence is listed as 8.8 feet and 5.8 feet.

There are two mining reports for this area each by a different Registered Professional Mining Engineer.

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(Avoca Quadrangle, block 1, element G1)

ITEM IX. This involves the location of the Nesbitt Memorial Hospital situated between Sharp and Poplar Streets on Wyoming Avenue in the Borough of Kingston. The area is designated as Class 1 on the map. The projected subsidence is listed as 1.9 feet.

The hospital is located over the abandoned workings of the former East Boston Colliery of the Payne Coal Company. From the early beginnings of mining at this mine, in the early 1890's, all of the breaker refuse was crushed and by the hydraulic flushing method was carried into the mine workings by pipe line for the purpose of filling the voids made in the removal of coal. The 1896 Report of the Pennsylvania Department of Mines will show that this was started in 1896. The primary reason for the flushing project was that there was not sufficient room on the surface to deposit the breaker tailings. The flushing included filling the voids made in final mining, that is the removal of pillars.

The Nesbitt Hospital sustained damage as a result of mining, which was minimal, in the years 1938 to 1941, inc. Repairs were made in the middle forties and there has been no further subsidence.

(Kingston Quadrangle, block 9, element F7)

ITEM X. This involves the "Barnum Site" located in the Borough of Duryea. The area is designated as Class 1 on the map. The projected subsidence varies from 8.4 feet to 22.8 feet.

There is a mining report made by Inspectors of the Pennsylvania Department of Mines and Mineral Industries in the year 1964 for this area which was under consideration for the Pittston Area High School. With exception of the Bottom Red Ash Vein and the Middle Red Ash Vein, which were mined as one vein, all other veins including Checker, Pittston, Marcy and Clark were completely mined between 1921 and 1939. The Middle Red Ash and Bottom Red Ash Veins were 60% mined and the voids made by the removal of the coal were completely collapsed.

(Pittston Quadrangle, block 3, elements I4, 5, 6; J4, 5, 6; block 6, elements A3, 4,5)

ITEM XI. This involves the "Turnpike Site" located in the rear of the Howard Johnson Motel and Northeastern Extension of the Pennsylvania Turnpike situated in Pittston Township. The area is designated as Class 1 on the map. The projected subsidence varies from 1.1 feet to 5.0 feet.

There is a mining report by a Registered Professional Mining Engineer for this site and in addition bore holes have been drilled.

(Pittston Quadrangle, block 6, elements G7, 8)

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ITEM XII. This involves the site of the Pittston Area High School situated in the rear of the southwesterly side of Stout Street, Borough of Yatesville, Luzerne County. The area is designated as Class 1 on the map. The projected subsidence varies from 7.5 feet to 12.0 feet.

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There is a mining report dated July 13, 1964, for this site made by a Commission of Mine Inspectors from the Pennsylvania Department of Mines and Mineral Industries for the Pennsylvania Department of Education.

Briefly the report states that the Pittston Vein, the top or surface vein, was completely mined and the area collapsed in 1921. The Marcy Vein, next below the Pittston Vein, was completed mined between 1934 and 1949 and further that the "Red Ash" Vein which is the bottom vein and 300 feet below the surface is solid in the entire area except for approximately 3 acres in the extreme easterly corner of the tract, which was completely mined in 1939. These three veins are the only veins of coal mined in this area.

Despite this the report projects a subsidence of between 7.5 feet and 12 feet.

(Pittston Quadrangle, block 5, element H10)

ITEM XIII. This involves the site of the new Pittston Area Elementary School located on New Street in the Borough of Hughestown, Luzerne County. The area is designated as Class 1 on the map. The projected subsidence is listed as 23.3 feet, 22.3 feet, 22.4 feet and 16.7 feet.

This is incredible as there is a mining report for this area by a Registered Professional Engineer and in addition the site had to be approved by the Department of Education.

(Pittston Quadrangle, block 6, element A4)

ITEM XIV. This involves the area occupied by the City of Nanticoke and the surroundin area. There is a total of 229 - 4 acre elements shown on the map, 163 of which are listed in Class 1. The projected subsidence varies from 0.1 feet to 11.4 feet.

Mining of coal has been going on under the City of Nanticoke since the early 1890's. It is a well known fact that subsidence has taken place in the City of Nanticoke over the years to about the middle forties. The voids made in the removal of coal are completely caved. To list this area as Class 1, Subsidence Imminent and of Potentially Damaging Magnitude, is also incredible.

(Nanticoke Quadrangle, block 6, elements A8, 9, 10; B8, 9, 10; C 8, 9, 10; D8, 9, 10; Wilkes-Barre Quadrangle, block 4, element E2)

ITEM XV. This involves the recently completed Luzerne County Community College. The area is designated as Class 1 on the map. The projected subsidence varies from 0.80 feet to 7.20 feet.

There is a mining report on this site and in additi~n the site had the approval of the Department of Education.

(Wilkes-Barre West Quadrangle, block 4, element E2)

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ITEM XVI. This involves the site of the new Industrial Park located between Market Street on the East, Northampton Street on the West, the former Lehigh Valley Railroad Passenger Station on the North, and the former Jersey Central Railroad Passenger Station on the South in the City of Wilkes-Barre. The area is designated as Class 1 and the projected subsidence is listed as 10.1 feet, 0.5 feet and 1.0 feet.

The underlying mine workings are a part of the abandoned workings of the former Hollenback Colliery where mining was abandoned approximately 40 years ago in the early 1930's. There has never been any subsidence in this area as the seams of coal are deep.

(Wilkes-Barre West Quadrangle, block 3, element C9, 10)

ITEM XVII. This involves the site on which the Veterans Hospital was built in the late 1940's and to which the first patient was admitted in November, 1950. The area is designated as Class 1 and the projected subsidence is listed as 9.4 feet and 4.3 feet.

I was a member of a two man commission of mine inspectors, appointed by the Secretary of Mines of the Commonwealth of Pennsylvania, at the request of the Veterans Administration in Washington, D. C. to make an inspection of the underground workings and to file a report with our findings and recommendations. The report was accepted and recommendations contained in the report were fulfilled.

This is the 25th Anniversary of the opening of the Veterans Hospital and to my knowledge there has never been any damage to the hospital as a result of subsidence.

I have used the above as an example of the many inaccuracies in the Report and as I further reviewed the maps I noted that there are at least several hundred similar conditions.

It is my opinion that the Report will have a disastrous effect on the Tax Structure in Lackawanna and Luzerne Counties is the Report is made public in its present form.

It is again recommended that the wording for Class 1 and Class 2 be changed to that agreed upon at meetings held on November 6th and 10th, and further that the proposed deletions from the Report and/or proposed changes in the wording as outlined on pages viii, xii, 6, 65, 80, 97, 101 and 106 of the Report, copies of which were furnished to those persons in attendance at the meetings on November 10, be made, together with the complete removal from the Report of Appendix A, pages 161 to 225, inclusive, and Appendix B, pages 227 to 264, inclusive. The proposed changes in the wording for Class 1 and Class 2 is not acceptable without the suggested deletions and changes as noted above.

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The proposed wording for Class 1 is as follows:

> "PRECUATIONARY AREA, SUBSIDENCE PROBABLE. IF NOT ALREADY PROGRESSED TO COMPLETION, SITE ENGINEERING REPORT NECESSARY."

I have two questions that I believe should be answered before the new definition for Class 1 is accepted which are as follows:

1. What is meant by site engineering report?
2. What is included?

If the engineering report is to include the drilling of test boreholes into the underlying mine workings it should not be accepted. It is my opinion that the owners of the Industrial Park or a client interested in either purchasing or leasing a part of the site should be the one to make a decision as to whether or not test boreholes are necessary.

On page 1 of the Report under 1. BACKGROUND, sub item 1. 2. DISCUSSION OF THE PROBLEM, paragraph 2, is the following:

> "In this coordinated program the full range of existing alternate strategies for coping with subsidence (flushing, insurance programs, architectural measures, etc.) is being explored for appropriate application. . ."

It is my opinion that a far greater service would be provided to the region if, in connection with the revision of the Classifications, the engineer would establish areas in the residential and business sections of the various municipalities where flushing projects should be initiated as soon as possible. In addition, it is my opinion that barren or undeveloped areas should not be given any consideration with respect to any flushing projects. In other words I do not believe that the engineering report should take into consideration any of the present or future Industrial Parks. In the past and in the future the underground conditions will be taken care of, as at present, with a mining report from a Registered Professional Engineer.

This is a rather lengthy summary but I have intentionally tried to included all of my thoughts pertaining to the Report.

DANIEL H. CONNELLY

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